



Closed Loop Controlled Dc-Dc Voltage Quadrupler

Aglare Emmanuel Das¹, Krishnakumar M²

PG Student [PE], Dept. of EEE, Vidya Academy of Science & Technology, Thrissur, Kerala, India¹

Assistant professor, Dept. of EEE, Vidya Academy of Science & Technology, Thrissur, Kerala, India²

ABSTRACT: A Closed Loop Controlled DC-DC Voltage Quadrupler is proposed. The proposed topology utilizes input-parallel output-series configuration for providing a higher voltage gain without using a large duty cycle. The converter can achieve high step-up voltage gain with the reduced number of components and also reduce the voltage stress of both active switches and diodes. This allows choosing a lower voltage rating MOSFETs and diodes to reduce both switching and conduction losses. Furthermore, by the charge balance of the blocking capacitor, the converter features automatic uniform current sharing characteristics of the two interleaved phases for voltage boosting mode while excluding extra circuitry or complex control strategies. The closed-loop controlled dc-dc voltage quadrupler converter is achieved using a microcontroller; the controller is designed such that the designed output voltage is held constant for a change in the input voltage for a fixed tolerance limit. The simulations are done in Matlab Simulink.

KEYWORDS: Closed Loop Control, Comparison of with and without feedback circuit, DC-DC converter, Voltage Quadrupler, Hardware implementation.

I. INTRODUCTION

The renewable energy sources such as solar cells and fuel cells are increasingly used worldwide for electric energy generation to replace energy from fossil fuel. The output voltage generated by the sources such as photovoltaic arrays, the fuel stacks or the battery sources are very low, in the range of 12-48 V. Due to the inherent low voltage characteristic of these sources, a high step-up dc converter is essential as a prestage of the corresponding power conditioner. Boost-type architecture with a large voltage gain is required to link this voltage to an inverter the conventional boost and buck-boost converters, due to the degradation in the overall efficiency as the duty ratio approaches unity [1], cannot fulfil the application need. Furthermore, an extremely large duty ratio not only induces very large voltage spikes and increases conduction losses but it also induces severe diode reverse-recovery problem [2].

The switched capacitor-based converters proposed in [3], [4] provide solutions to improve the conversion efficiency and achieve a large voltage conversion ratio. Unfortunately, the conventional switched capacitor technique makes the switch suffer high transient current and large conduction losses. But in order to obtain an extremely high step-up conversion, many switched capacitor cells are required which increases the circuit complexity [5].

A traditional boost converter can achieve an infinite voltage gain as the duty cycle approaches 100 percentage in theory, but in practice, the leakage resistance in the inductor-charging loop limits the boost ratio. Due to this reason, a boost converter is not preferred when the required boost ratio is higher than four. The interleaved voltage doubler [6] has been proposed for universal line power factor correction front end with automatic current sharing capability and lower active switch stress to increase the low-line efficiency. But the voltage gain is not high enough and the diode voltage stress remains very high. To achieve a higher voltage conversion ratio and further reduce voltage stress on the switch and diode, the high step-up ratio converter [7] and the ultrahigh step-up converter [8] have been proposed. These mentioned converters have large step-up voltage conversion ratios. But they do have the disadvantage of the voltage stress of diodes in those converters remains rather high. Another important requirement is to drain a continuous current with minimum ripple. Therefore, converters having both these features are found useful in many applications within the renewable-energy context. In PV applications, the ripple in current impacts the generated power since an oscillation is created around the MPP reducing the energy extracted from the photovoltaic generator. These characteristics make the



International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 6, June 2019

boost converter a good candidate to interface the photovoltaic systems. Another possibility to reduce the converter's input current ripple is given by the interleaving structures. The interleaved structure can effectively increase the switching frequency and reduce the input and output ripples as well as the size of the energy storage inductors. The proposed system has a two-phase interleaved boost converter to realize a high voltage gain, maintain the advantage of an automatic current sharing capability simultaneously, high efficiency, low input current ripple, and better transient responses. And the added advantage of, the voltage stress of active switches and diodes in the proposed converter can be greatly reduced to enhance overall conversion efficiency.

II.LITERATURE SURVEY

Before the development of power electronic (PE) devices one way to convert the voltage of a DC supply to a higher voltage, for low-power applications, was to convert it to AC by using a rotating machine followed by a step-up transformer and rectifier. These were relatively inefficient and expensive procedures. With the onset of PE devices and IC's made it economically viable to use techniques as to convert the DC power supply to high-frequency AC, with small transformer which is light, and cheap due to the high frequency to change the voltage, and rectify back to DC. Practical electronic converters use switching techniques. DC level higher or lower than the input is acquired by storing and releasing the energy to at different voltage levels commonly called switched-mode converters. The recent increase in fossil fuel cost and new regulations to reduce CO₂ emissions have increased the interest in renewable energy resources in general. Fuel cells and photovoltaics (PVs) have been gaining a lot of interest as leading renewable energy technologies. A PV output voltage is a function of irradiation, which causes it to also vary. But the low variable voltage of the renewable energy technologies calls for a high-efficiency high-ratio dc-dc converter. The output voltage of a conventional boost converter to be approximately four times its applied voltage due to the practical considerations. In order to supply a high output voltage, the conventional boost converter must operate at extremely high duty cycle ratios. Large duty cycles put inefficiently small off times or lower switching frequencies. The electromagnetic interference (EMI) levels are increased due to the smaller off which causes very severe diode reverse recovery current which in turn increases EMI. And Lower switching frequency leads to greater ripple current and adds magnetic components. Moreover, an extreme duty cycle is not desirable since no room is left for control to compensate changes in a load or a line. And high power rated semiconductor devices are needed for a conventional high step-up boost converter. The drawback associated with that is the size, cost, and degradation of the overall converter efficiency. The aforementioned and related drawbacks associated with existing high step-up boost converters encourage a search for better high step-up converter topology which enables the use of a lower voltage rated Switches and diodes for increasing better efficiency by reducing the conduction as well as the switching losses.

Gain/stress	Voltage Doubler	High step-up ratio converter	Ultra high step up converter	Proposed converter
Voltage gain	$\frac{2}{1-D}$	$\frac{3-D}{1-D}$	$\frac{3+D}{1-D}$	$\frac{4}{1-D}$
Voltage stress of switches	$\frac{1}{2}$	$\frac{1}{3-D}$	$\frac{2}{3+D}$	$\frac{1}{4}$
Voltage stress of diodes	1	$\frac{2}{3-D}$	$\frac{2}{3+D}$	$\frac{1}{2}$
Number of Mosfets	2	2	1	2
Number of inductors	2	2	2	2
Number of Diodes	2	3	5	4
Number of Capacitors	2	3	4	4

Table 1-Comparison of different converter topologies



International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 6, June 2019

The table 1 shows the comparison of four different boost converter topologies the voltage gain, component count, as well as the voltage stress across the semiconductor devices.

Duty ratio	Voltage Doubler	High step-up ratio converter	Ultra high step up converter	Proposed converter
.50	4	5	7	8
.55	4.44	5.44	7.88	8.88
.60	5	6	9	10
.65	5.714	6.714	10.42	11.42
.70	6.66	7.66	12.33	13.33
.75	8	9	15	16
.80	10	11	19	20
.85	13.33	14.33	25.66	26.66

Table 2- Relation between duty ratio and voltage gain of different converter

The table 2 is formed from the voltage gain equations form table 1, for the same duty ratio the voltage gain of the different boost converter are calculated and tabulated.

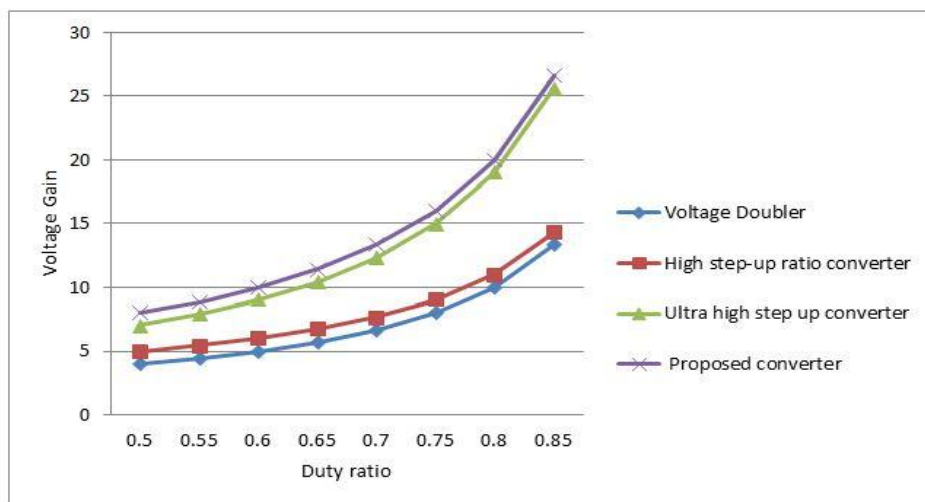


Figure 1-Graph plotted between Voltage gain vs Duty ratio

Figure1 is the graphical representation of the table 2; it simply shows the advantage of the proposed converter over other boost converter.

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 6, June 2019

III.METHODOLOGY

3.1-BLOCK DIAGRAM

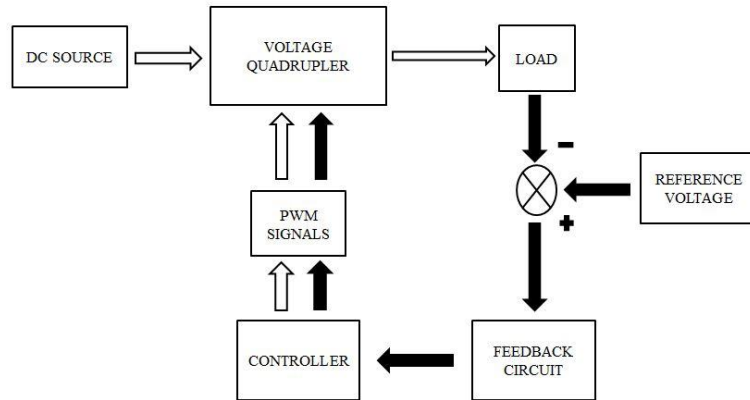


Figure 2-Block diagram of proposed converter

The Figure 2 shows the block diagram of a closed-loop controlled dc-dc voltage quadrupler. The dc source supplies power to the voltage quadrupler topology and the output voltage is measured and compared with the reference voltage. The voltage difference between the reference voltage and actual voltage is fed back to the controller. The controller adjusts the switching pulses to make the actual voltage identical as that of the required voltage.

The block diagram with white arrows shows the existing topology [A Novel Transformer-less Adaptable Voltage Quadrupler DC Converter with Low Switch Voltage Stress]-[11]. And the Black arrows shows the modification done in order to modify the existing topology to have a closed loop feedback control.

3.2-CIRCUIT DIAGRAM

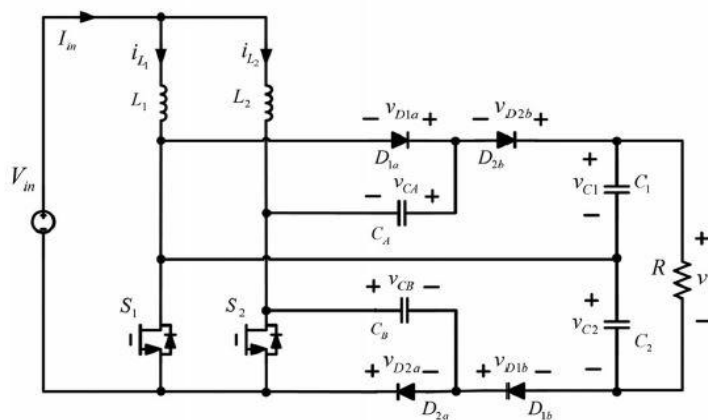


Figure 3-Voltage quadrupler topology

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 6, June 2019

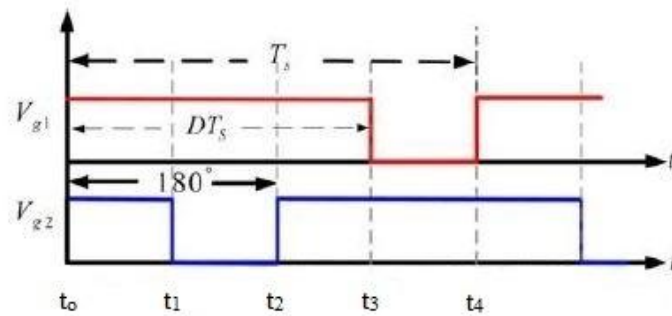


Figure 4-Shows the switching pulses in different modes

There are four modes of operation for the operating principle behind the proposed converter.

Mode 1, ($t_0 \leq t \leq t_1$): Switches S_1 and S_2 are turned ON, D_{1a} , D_{1b} , D_{2a} and D_{2b} are all OFF. Both I_{L1} and I_{L2} are increasing to store energy in L_1 and L_2 , respectively. The voltages across diodes D_{1a} and D_{2a} are clamped to capacitor voltage V_{CA} and V_{CB} , respectively, and the voltages across the diodes D_{1b} and D_{2b} are clamped to V_{C2} minus V_{CB} and V_{C1} minus V_{CA} , respectively. Also, the load power is supplied from capacitors C_1 and C_2 .

Mode 2, ($t_1 \leq t \leq t_2$): For this operation mode, switch S_1 remains conducting and S_2 is turned OFF. Diodes D_{2a} and D_{2b} become conducting. Part of stored energy in inductor L_2 as well as the stored energy of C_A is now released to output capacitor C_1 and load. Meanwhile, part of stored energy in inductor L_2 is stored in C_B .

Mode 3, ($t_2 \leq t \leq t_3$): Both S_1 and S_2 are turned ON. Similar to the first mode of operation.

Mode 4, ($t_3 \leq t \leq t_4$): For this operation mode, switch S_2 remains conducting and S_1 is turned OFF. Diodes D_{1a} and D_{1b} become conducting. The part of stored energy in inductor L_1 as well as the stored energy of C_B is now released to output capacitor C_2 and load. While, part of stored energy in inductor L_1 is stored in C_A .

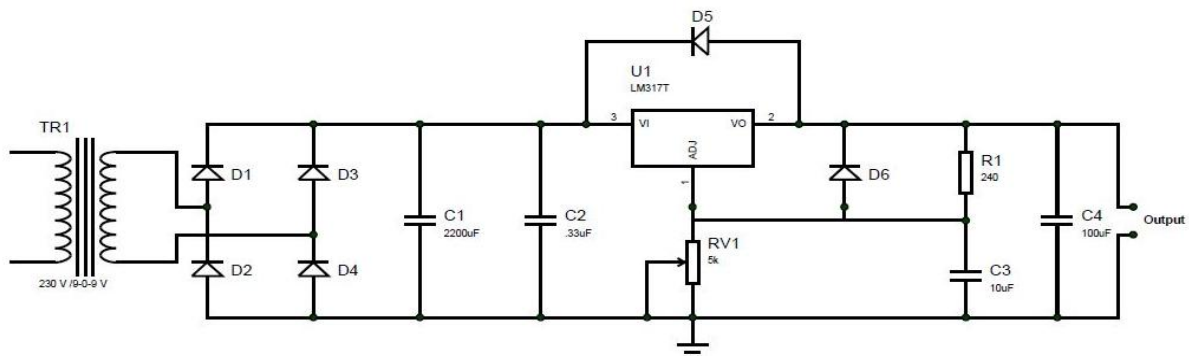


Figure 5-Variable DC supply

The figure 5 shows a variable dc supply. The circuit utilizes an LM317T a variable voltage regulator for its operation. The variable dc supply can be used to power the proposed converter. There by changing the input voltage value as desired.

$$R_2 = R_1 \left(\left(\frac{V_{out}}{1.25} \right) - 1 \right)$$

Taking $V_{out} = 18 \text{ V}$

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 6, June 2019

R_1 and R_2 can be found from the equation. R_2 is a potentiometer.

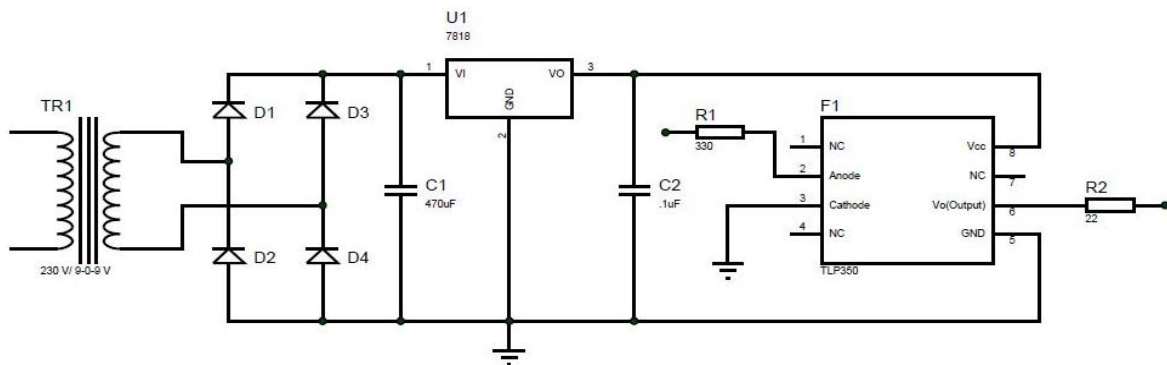


Figure 6-Optocoupler circuit

The circuit of an optocoupler (TLP350) is shown; the optocoupler helps in controlling the Mosfets without putting strain on the microcontroller. Driver IC's are often used for high current MOSFETs and when using fast switching rates due to the MOFETs needing brief but high currents to change state. Driver's inputs are typically logic level. Often MOSFETS require a 1-2 A drive to achieve switching efficiently at frequencies of hundreds of kilohertz. This drive is required on a pulsed basis to quickly charge and discharge the MOSFET gate capacitances.

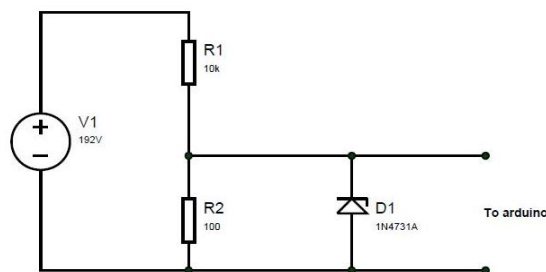


Figure 7-Voltage divider

For controlling the proposed converter Arduino UNO is selected it can generate the PWM signals necessary for controlling the Mosfets. The down side is that Arduino cannot drive the mosfet directly so optocoupler are used as an interface between the both. The output voltage is extremely high as the Arduino can only accept a maximum of 5 volts as a feedback value. So a solution to this problem is to use a voltage divider to step down the voltage to a tolerable level for the Arduino. A Zener diode is also used for protection in any case a voltage higher than the threshold value reaches the controller.

IV.DESIGN

For the proposed topology the voltage gain is given by,

$$\frac{V_o}{V_{in}} = \frac{4}{1 - D}$$

Since the topology is a voltage quadrupler we can find the duty ratio and output voltage by just knowing the input voltage. As the input voltage is taken as 12 V the output voltage must be a quadrupled value that is 192 V. From the equation we can substitute for input and output voltage and find the duty ratio.

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 6, June 2019

Design for a system of $V_{in} = 12\text{ V}$, $V_{out} = 192\text{ V}$, $D = .75$,

$$P = \frac{V^2}{R}$$

Taking $P = 75\text{ W}$, $R = 491.52\ \Omega$ taken as $500\ \Omega$,

Since we know the power and voltage the current is calculated to be

$$I = .3906\text{ A}$$

The inductor current ripple peak-peak amplitude is given by

$$\Delta I_1, I_2 = \frac{V_{in} D}{f_s L}$$

The value of the capacitor is given by the formula,

$$f_s = 40 \times 10^3$$

$$C = \frac{DV_o}{R\Delta V_o f_s}$$

$$C = 3.6 \times 10^{-6}\text{ F}$$

The expression for finding the value of inductor is,

$$L = \frac{V_{in} D T_s}{2\Delta I_o}$$

$$L = 1.125 \times 10^{-4}\text{ H}$$

V.SIMULATION

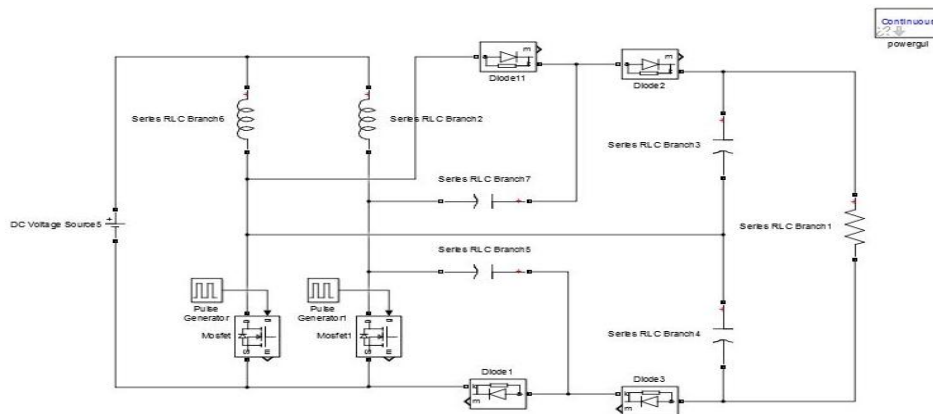


Figure 8-Simulation of voltage quadrupler in open loop

All simulations are done in Matlab Simulink the figure 8 shows the simulation of voltage quadrupler in open loop manner

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 6, June 2019

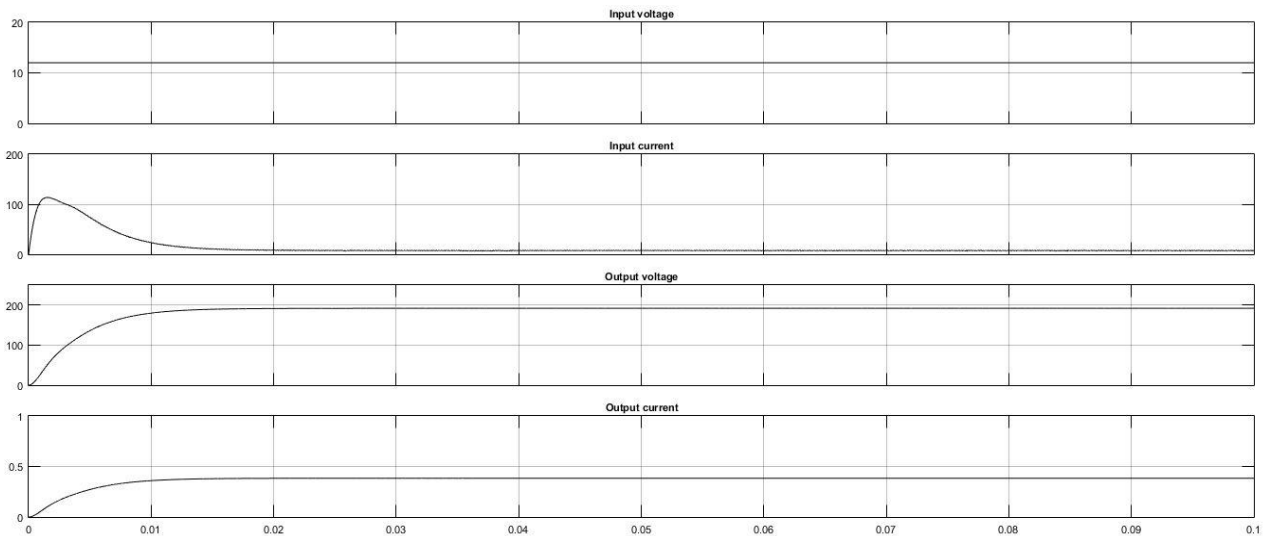


Figure 9-Voltage and current waveforms of without feedback topology

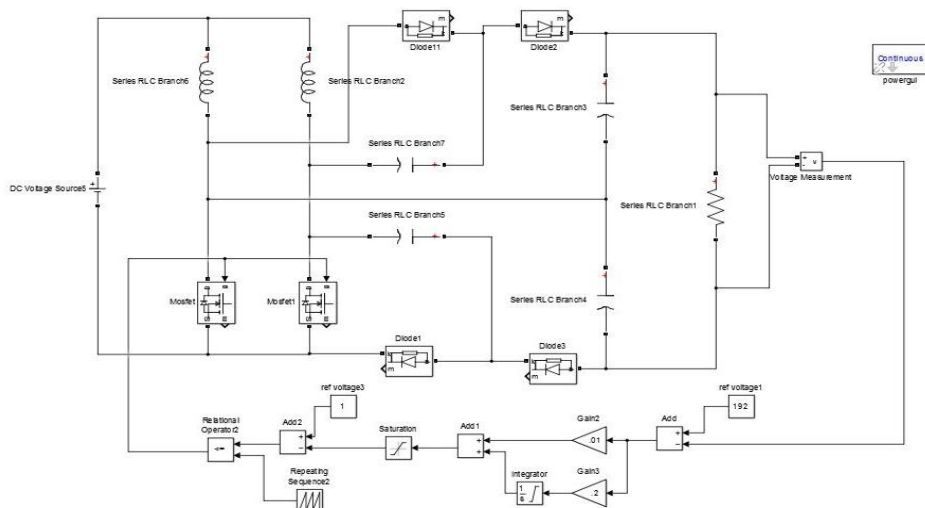


Figure 10-Proposed converter with feedback circuit-1

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 6, June 2019

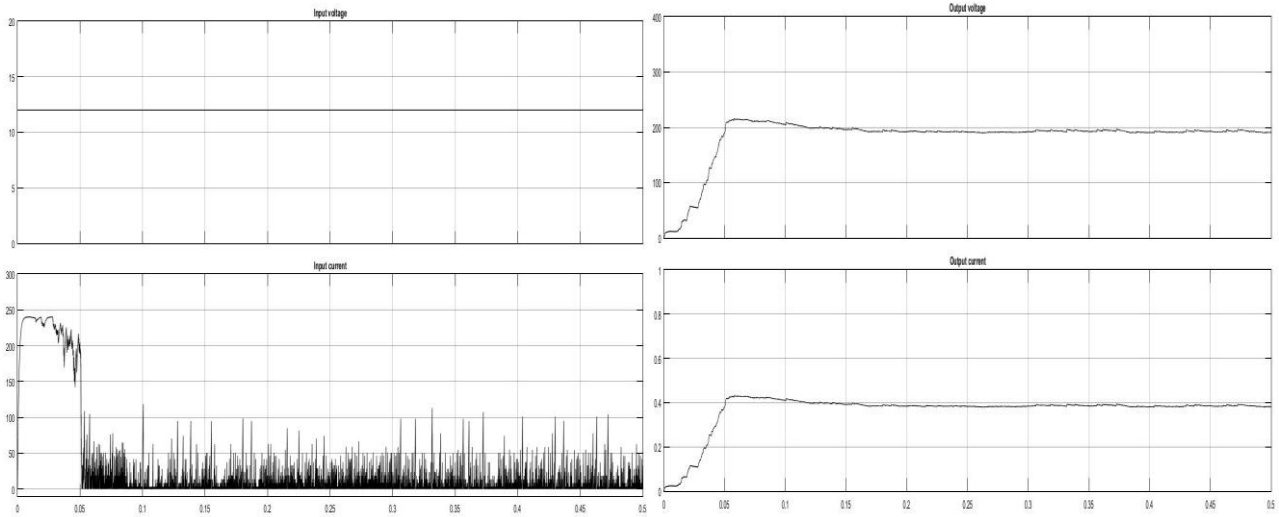


Figure11-Voltage and current waveforms of with feedback circuit-1

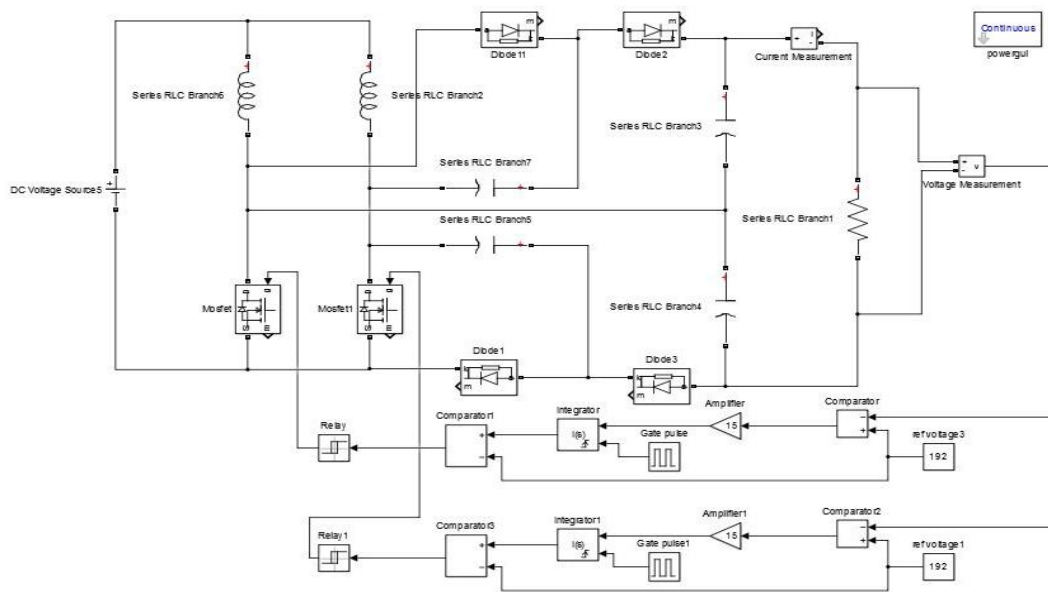


Figure12-Proposed converter with feedback circuit-2

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 6, June 2019

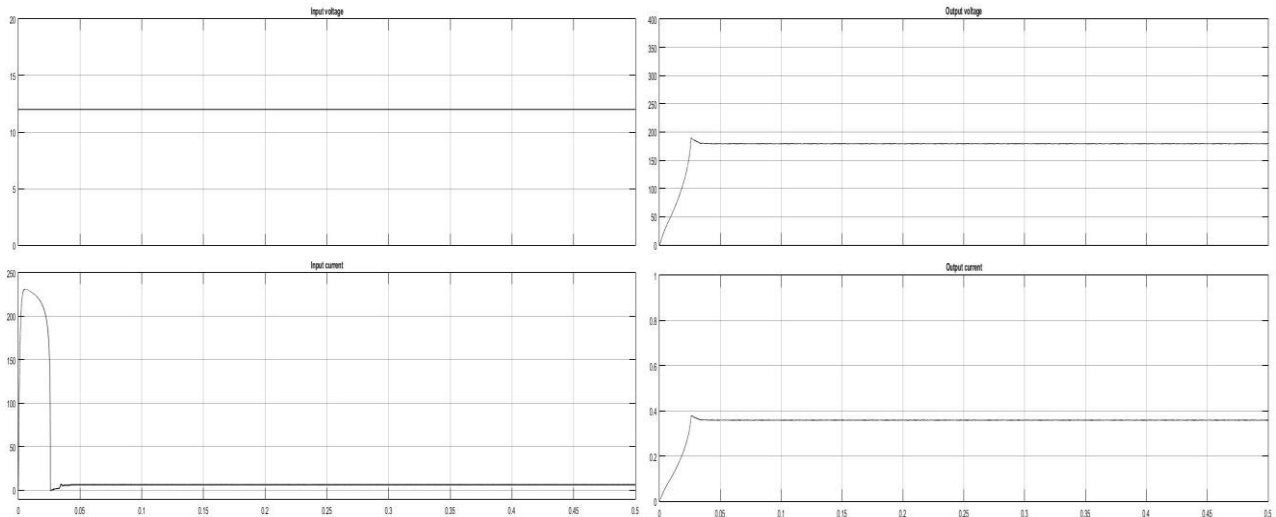


Figure13-Voltage and current waveforms with feedback circuit-2

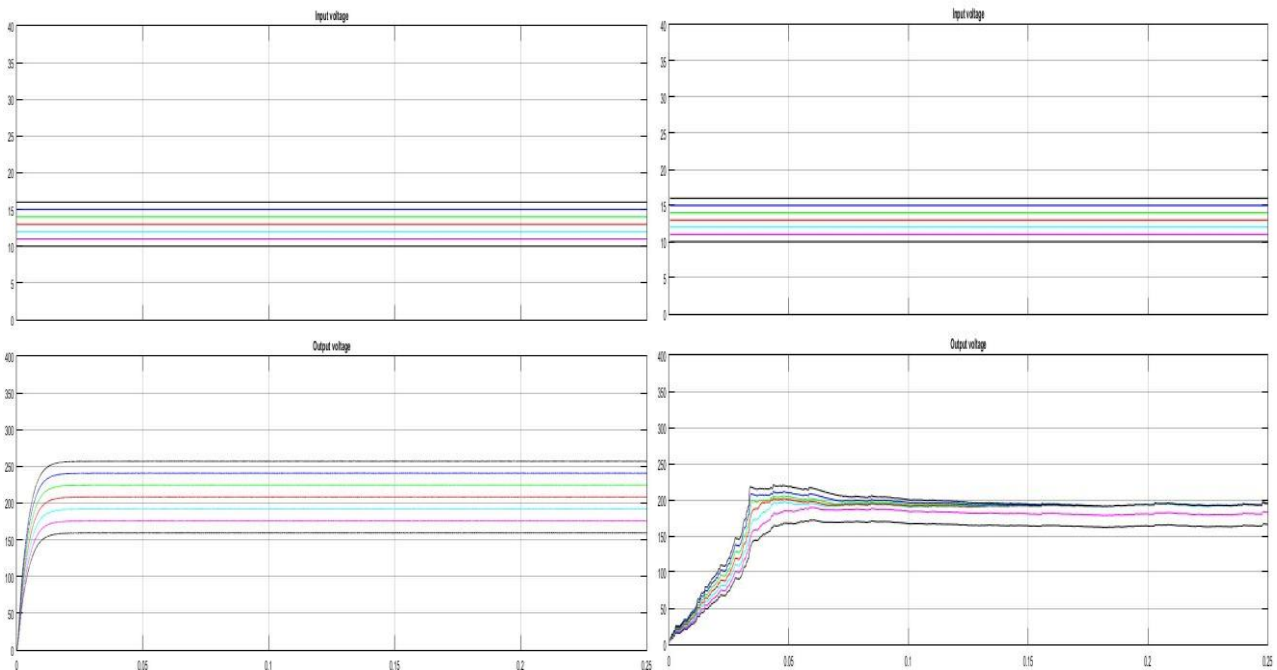


Figure 14-Input voltage & Output voltage with and without feedback

Simulation shows the operation of the voltage quadrupler for with and without feedback, on the left quadrupler is working on open loop basis the output is directly depending on the input voltage. But on the right hand side the quadrupler is working with feedback loop the output is kept constant at the designed value for whatever be the input voltage provided it falls within the designed tolerance range.

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 6, June 2019

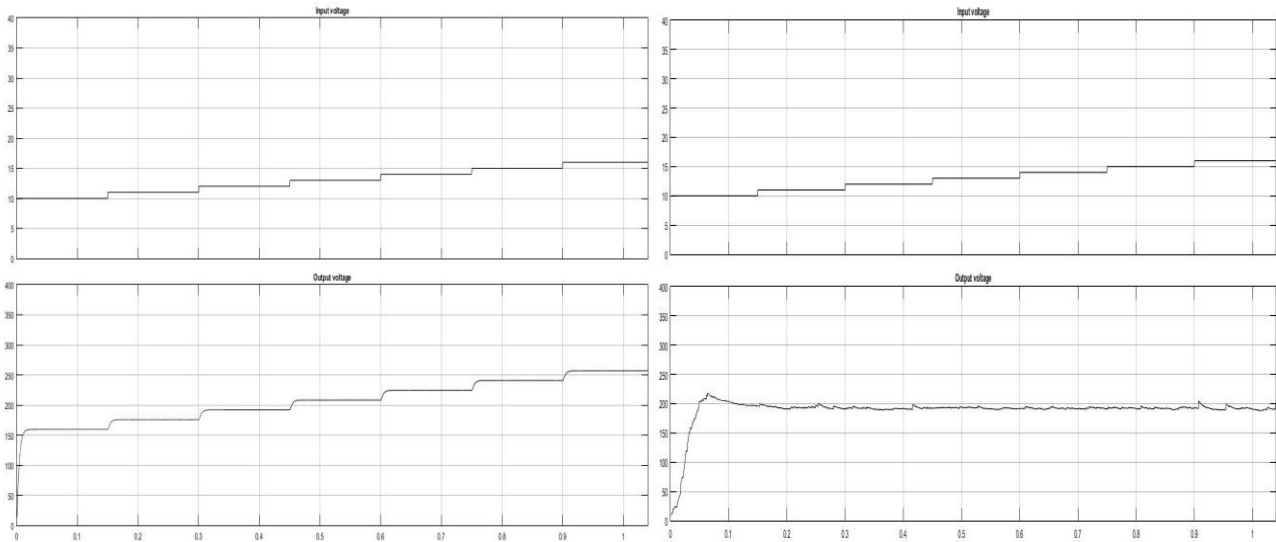


Figure15-Input voltage & Output voltage with and without feedback with transient response

Figure 15 shows the transient response of the converter as the input changes the output also changes for without feedback simulation shown on the left side and on the right side the converter is working with feedback and the output voltage is held constant for the changes in input voltage.

Input voltage	Without feedback	With feedback Loop-1	With feedback Loop-2
10	159.4	189.7	176.9
11	175.7	191	178.2
12	191.9	191.4	179.4
13	208.2	191.7	180.3
14	224.4	190.1	181.1

Table-3 Input voltage and the corresponding output voltage

The table shows the different input voltages and the corresponding output voltages for with and without feedback topologies. There are two different feedback topologies designed in Matlab simulink.

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 6, June 2019

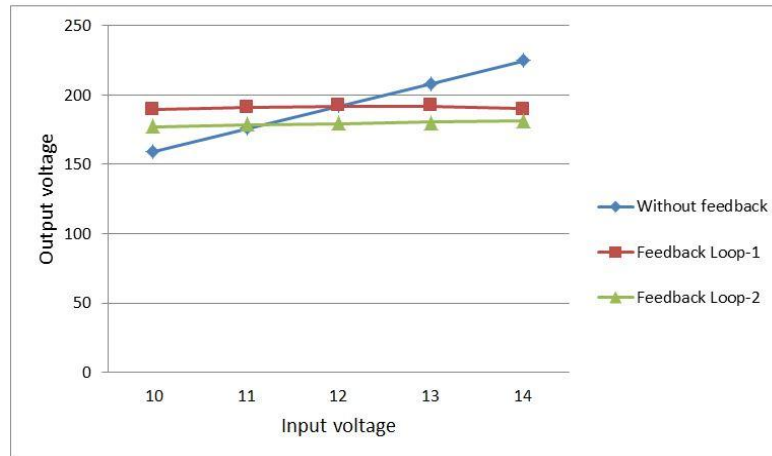


Figure 16-Input voltage vs Output voltage

The figure shows the graphical representation of the Table-3 here we can see that without feedback line steadily increases and the with feedback loop-1 and 2 are fairly constant that is the outout is held constant even though the input voltage changes.

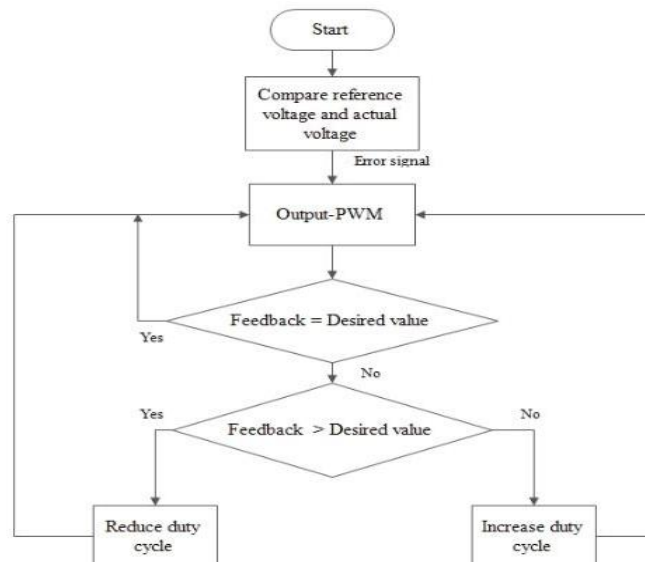


Figure-17 Flowchart of closed loop control operation

The above flowchart shows the stepwise operation carried out in order to keep the output voltage constant. The actual output voltage is measures and compared with the reference voltage the error thus generated is fed to the controller. The aim is to make the reference voltage and actual voltage same as possible. Certain conditions are put in place such as if the output voltage is less than the desired value then the duty cycle is increased and vice versa if the output voltage is higher than designed value .

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 6, June 2019

V. RESULT AND DISCUSSION

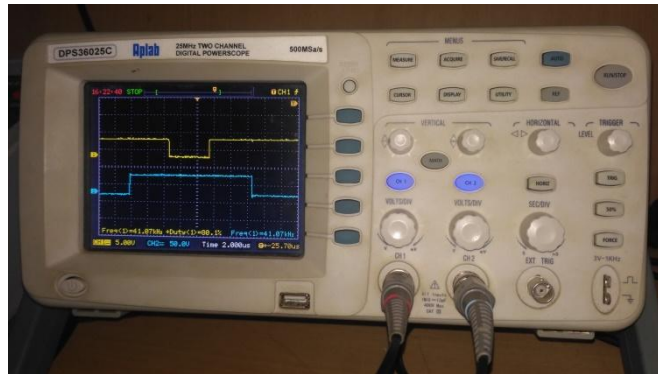


Figure 18- Switching pulses for the Mosfets

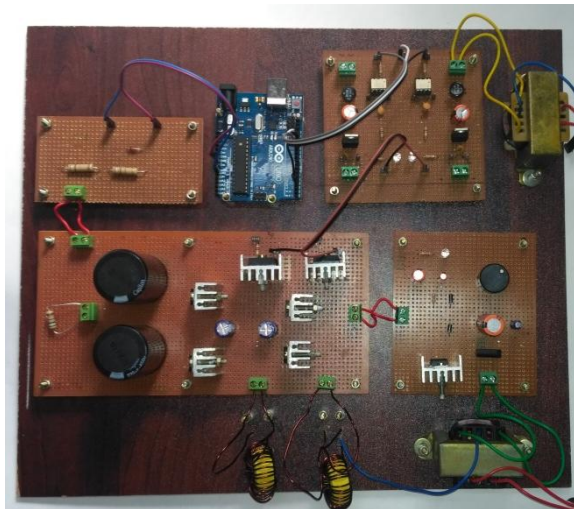


Figure 19-Shows the complete hardware of the closed loop controlled DC-DC voltage quadrupler

VI.CONCLUSION

A closed loop controlled dc-dc voltage quadrupler is designed, simulated, fabricated and tested. The circuit was designed for an input voltage of 12 volts and an output voltage of 192 volts. And for a variation in input voltage (20 % of the designed input voltage) the output is held constant. For the purpose of this project work a converter [A Novel Transformer-less Adaptable Voltage Quadrupler DC Converter with Low Switch Voltage Stress]-[11] is taken as the reference converter and modified such that it can function in a closed loop manner. The simulation of the converter in open loop and closed loop manner is done.

REFERENCES

- [1] R. W. Erickson and D. Maksimovic, "Fundamentals of Power Electronics", 2nd ed. Norwell, MA, USA: Kluwer, 2001.
- [2] Q. Zhao, F. Tao, F. C. Lee, P. Xu, and J. Wei, "A simple and effective to alleviate the rectifier reverse-recovery problem in continuous-current-mode boost converter," IEEE Trans. Power Electron., vol. 16, no. 5, pp. 649658, Sep. 2001.



ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 8, Issue 6, June 2019

- [3] F. Zhang, L. Du, F. Z. Peng, and Z. Qian, "A new design method for high power high-efficiency switched-capacitor DC-DC converters," IEEE Trans. Power Electron., vol. 23, no. 2, pp. 832840, Mar. 2008.
- [4] B. Axelrod, Y. Berkovich, and A. Ioinovici, "Switched-capacitor/ switched inductor structures for getting transformer less hybrid DC-DC PWM converters," IEEE Trans. Circuits Syst. I, Reg. Papers, vol. 55, no. 2, pp. 687696, Mar. 2008.
- [5] W. Li, X. Xiang, C. Li, W. Li, and X. He, "Interleaved high Step-Up ZVT converter with built-in transformer voltage doubler cell for distributed PV generation system," IEEE Trans. Ind. Electron., vol. 28, no. 1, pp. 300313, Jan.2013.
- [6] Y. T. Jang and M. M. Jovanovic, "Interleaved boost converter with intrinsic voltage-doubler characteristic for universal-line PFC front end," IEEE Trans. on Power Electron., vol. 22, no. 4, pp. 13941401, Jul. 2007.49
- [7] L. S. Yang, T. J. Liang, and J. F. Chen, "Transformer less DC-DC converters with high step-up voltage gain," IEEE Trans. Ind. Electron., vol. 56, no. 8, pp.31443152, Aug. 2009.
- [8] A. A. Fardoun and E. H. Ismail, Ultra step-up DC-DC converters with reduced switch stress, IEEE Trans. Ind. Appl., vol. 46, no. 5, pp. 2025 2034, Oct. 2010.
- [9] Chitra.P and Seyezhai.R"Basic Design and Review of Two Phase and Three Phase Interleaved Boost Converter for Renewable Energy Systems" International Journal of Applied Science .05 July 2014
- [10] S. Masri, P. W. Chan "Design and Development of DC-DC boost converter with constant output voltage" School of Electrical and Electronic Engineering, Universiti Sains Malaysia, 14300 Nibong Tebal, Seberang Prai Selatan, PulauPinang, Malaysia
- [11] Ching-Tsai Pan, Chen-Feng Chuang, Chia-Chi Chu,"A Novel Transformer less Adaptable Voltage Quadrupler DC Converter with Low Switch Voltage