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ANALYSIS AND MODELING OF TRANSFORMER LESS HIGH GAIN BUCK-BOOST DC-DC CONVERTER FOR SOLAR ENERGY APPLICATION

Y. Sai Sruthi[*1] & M. Siva Kumar[2]

[*1]P.G. Student, Department of Electrical and Electronics Engineering, Sri Padmavathi Mahila Visvavidyalayam, Tirupathi-517502

[2]Assistant Professor, Department of Electrical and Electronics Engineering, SriPadmavathiMahila Visvavidyalayam,Tirupathi-517502

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ABSTRACT

This paper proposes a transformer less buck boost converter model usedfor solar energy application, which provides, higher efficiency and its voltage gain is quadratic of the traditional buck-boost converter. It can operate in a wide range of output voltage, that is, the proposed buck-boost converter can achieve high or low voltage gain without extreme duty cycle. Moreover, the output voltage of this transformer less buck-boost converter is common-ground with the input voltage, and its polarity is positive. The two power switches of the buck-boost converter operate synchronously. The operating principles of the buck-boost converter operating in continuous conduction modes are presented. The new transformerless buck-boost converter is analyzed by providing required DC voltage frompv array as input to the converter. The simulation results are presented to confirm the capability of the converter to generate high voltage ratios. The comparison between the proposed converter and the traditional converter is also analyzed to reveal the improved voltage gain. The proposed converter is suitable for a wide application which requires high step-up DC-DC converters such as DC micro-grids and solar electrical energy.

KEYWORDS: DC-DC Power Conversion, Buck Boost Converter, PWM, PI Controller.

I. INTRODUCTION

In recent years use of electrical equipment and electrical energy has increased very rapidly. As the demand for power is significantly increasing day by day, renewable energy sources have received a lot of attention as an introduced alternatives way of generating directly electricity. By Using different renewable energy sources can eliminate harmful emissions from polluting the environment while it also offers inexhaustible resources of primary energy. There are many sources of renewable energy, such as solar energy, wind turbines, and fuel cells. However, fuel cells and solar cells have low output voltage [2], [3], [4]. Thus, a high efficiency and step-up DC-DC converter is desired in the power conversion systems to increase the voltage supplied to the grid or be compatible in other applications.Theoretically, the proposed buck boost DC-DC converter can provide a very high voltage gain by using an extremely high duty cycle. However in actual application, for a very high duty cycle, the voltage gain is reduced because of the non-ideal elements in circuits such as inductors, capacitors, switches, diodes, etc. Moreover, extremely high duty cycle can create electromagnetic interference [5] [6], which might diminish the efficiency of the operation of circuits.

Several researchers have designed models that can achieve high voltage gain. Step-up converter using transformer is presented in [7] [8] [9]. They can control the voltage gain by creating a conversion ratio function of the duty ratio and the transformer turns ratio. However, its efficiency will dramatically degrade by losses associated with the leakage inductance, and may cause power losses and heat dissipation problems [10] [11]. Main disadvantage is the size and weight of the transformer, which is often desired to be as compact as possible. Switching mode power supply is the core of modern power conversion technology, which is widely used in electric power, communication system, household appliance, industrial device, railway, aviation and many other fields. On the basis of switching mode power supply, converter topologies are attracting a great deal of attention and many converter topologies have been proposed to overcome the disadvantages. Both Buckconverter and boost converter have the simple structure and high efficiency. However, due to the limited voltage gain, their applications are restricted when the low or high output voltage are needed. The traditional buck-boost converter with simple structure and high efficiency, as we all know, has the drawbacks such as limited voltage gain, negative output voltage, floating power switch, meanwhile dis-continuous input and output currents.The transformer less buck-boost converter is obtained by inserting an additional switched network into the traditional buck-boost converter. The main merit of the proposed buck-boost converter is that its voltage gain is quadratic times that of the traditional buck-boost converter so that it can operate in a wide range of output voltage, that is, the proposed transformer less buck-boost converter can achieve low or high voltage gain without any extreme duty cycle. Moreover, the output voltage of theproposed new transformerless buck-boost converter is common-ground with the input voltage, and its polarity is positive[1]. Hence to deal with low-voltage photovoltaic (PV) arrays and to provide higher voltage as output, a transformerless buck boost converter is proposed based on the traditional buck boost converter structure. The proposed model is simple, which includes only two inductors, two capacitors and two power switches and two diodes, and thus, it is very easy to implement. The proposed converter will not only provide high voltage gain, but also reduce the extremely high duty cycles of power switches, and increase the efficiency of the converter. This paper proposes a new transformerless buck boost converter with a feedback to obtain constant output voltage regardless of varying load conditions for solar energy application and it operates in simple operating modes. The complete system is simulated in Matlab and results were obtained.

II. TRANSFORMERLESS BUCK-BOOST CONVERTER WITH POSITIVE OUTPUT VOLTAGE AND FEEDBACK

A new transformerless buck-boost converter structure is obtained by inserting an additional switched network into the traditional buck-boost converter. The main merit of the proposed buck-boost converter is that its voltage gain is quadratic times that of the traditional buck-boost converter so that it can be operated for a wide range of output voltage, that is, the proposed buck-boost converter can achieve high or low voltage gain without any extreme duty cycle. Moreover, the output voltage of this new transformerless buck-boost converter is common-ground with the input voltage, and its polarity is positive.

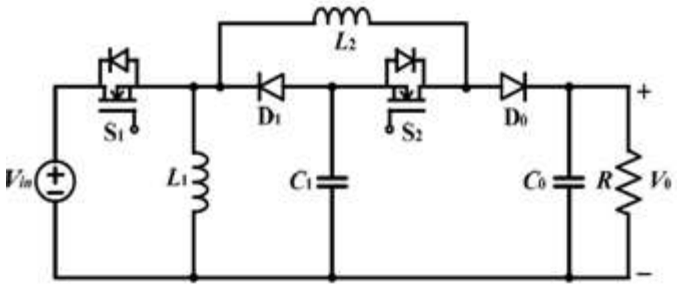

Fig 1: Proposed converter

a) Converter Structure

The structure of the new transformerless buck-boost converter is shown in fig-1. It consists of two Mosfets (S1 and S2), two diodes (D1 and DO), two inductors (L1 and L2), two capacitors (C1 and Co), and resistive load R. Mosfets S1 and S2 are controlled synchronously. According to the state i.e. whether ON or OFF of the Mosftes and diodes, The operating time-domain waveforms of the proposed new transformerless buck-boost converter operating in CCM are shown in fig- 2, and the two operating states of the proposed buck-boost converter are shown in figures 3 and 4. Figure 3, it denotes that the power switches S1 and S2 are turned on whereas the diodes D1 and DO do not conduct. Consequently, both the inductor L1 and the inductor L2 are magnetized, and both the charge pump capacitor C1 and the output capacitor CO are discharged. Figure 4, it describes that the power switches S1 and S2 are turned off while the diodes D1 and DO conduct for its forward biased voltage. Hence,both the inductor L1 and the inductor L2 are demagnetized, and both the charge pump capacitor C1 and the output capacitor CO are charged. It clearly represents that during the mosfets are ON inductors are Magnetized and when OFF inductors are demagnetized.

b) Operating Principles

As shown in fig-2, there are two operating modes, that is, mode 1 and mode 2, in the new transformerless buck-boost converter when it operates in CCM operation. Mode 1 between time interval (NT<t<(N+D)T). Mode 2 between time interval ((N+D) T<t<(N+1)T).

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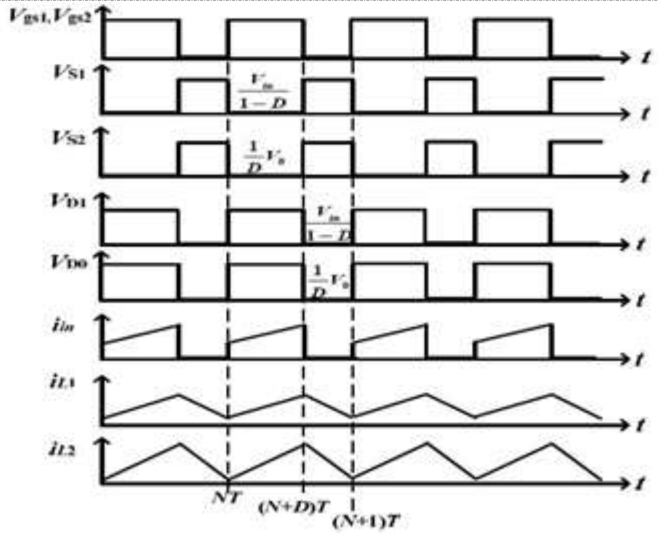

Fig 2: Typical Time-Domain Waveforms for the Buck-Boost Converter Operating in CCM.

- **Mode 1(NT<t<(N+D)T)**

Mode 1 is during the time interval (NT<t<(N+D)T). During this time interval, the switches S1 and S2 are turned on, while D1 and DO are reverse biased. From fig-3, it is seen that L1 is magnetized from the input voltage Vin while L2 is magnetized from the input voltage Vin and the charge pump capacitor C1. Also, the output energy is supplied from the output capacitor CO. Thus, the corresponding equations can be established as,

$$V_{L1}= Vin \qquad (1)$$

$$V_{L2}= Vin + V_{C1} \qquad (2)$$

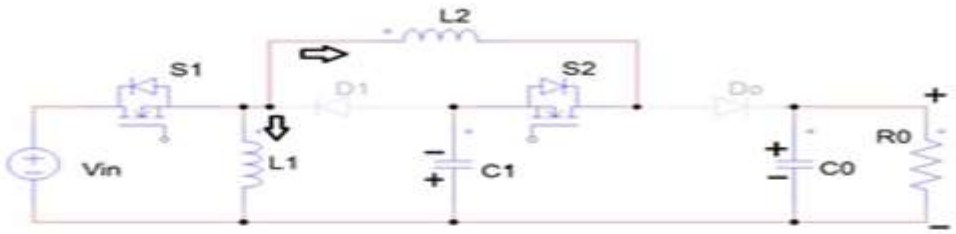

Fig 3: Equivalent circuit of the buck-boost converter in mode 1

- **Mode 2[$t_1 - t_3$] ((N+D)T<t<(N+1)T)**

State 2 is during the time interval ((N+D)T<t<(N+1)T). During this time interval, the switches S1 and S2 are turned off, while D1 and DO are forward biased. From fig- 4, it is seen that the energy stored in the inductor L1 is released to the charge pump capacitor C1 via the diode D1. At the same time, the energy stored in the inductor L2 is released to the charge pump capacitor C1, the output capacitor CO and the resistive load R via the diodes DO and D1. The equations of the state 2 are described as follows

$$VL1= -VC1 \qquad (3)$$

$$VL2=-(VC1+VO) \qquad (4)$$

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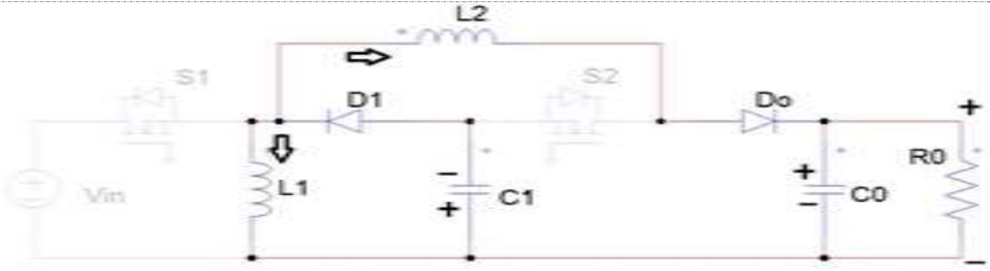

Fig 4: Equivalent circuits of the buck-boost converter in mode 2.

If applying the voltage-second balance principle on the inductor L1, then the voltage across the charge pump capacitor C1 is readily obtained from equations (1) and (3) as

V_{C1}={D/(1-D) }Vin ....(5)

Here, D is the duty cycle, which represents the proportion of the power switches turn on time to the whole switching cycle. Similarly, by using the voltage-second balance principle on the inductor L2, the voltage gain of the proposed buck-boost converter can be obtained from equations (2), (4), and (5) as

M=VO/Vin = (D/(1-D))2.................................. (6)

From equation (6), it is apparent that the proposed buck-boost converter can step-up the input voltage when the duty cycle is bigger than 0.5, and step-down the input voltage when the duty cycle is smaller than 0.5.

III. SIMULATION MODEL AND RESULTS

a) Simulation Model

The circuit of the new transformer less buck-boost converter is simulated using the Matlab software to confirm the aforementioned analyses. The input DC voltage is given through the pv array which uses solar cells to generate the required dc voltage of 18 volts. In order to deal with low-voltage photovoltaic (PV) arrays and the required higher voltage of the grid, a transformer less buck boost converter is proposed based on the traditional buck boost converter. Circuit parameters chosen are shown in the table.

Parameter	Value
Vin	18v
fs	20kHz
D	0.4-0.6
L1	1mH
L2	3mH
C1	10µF
C2	20 µF

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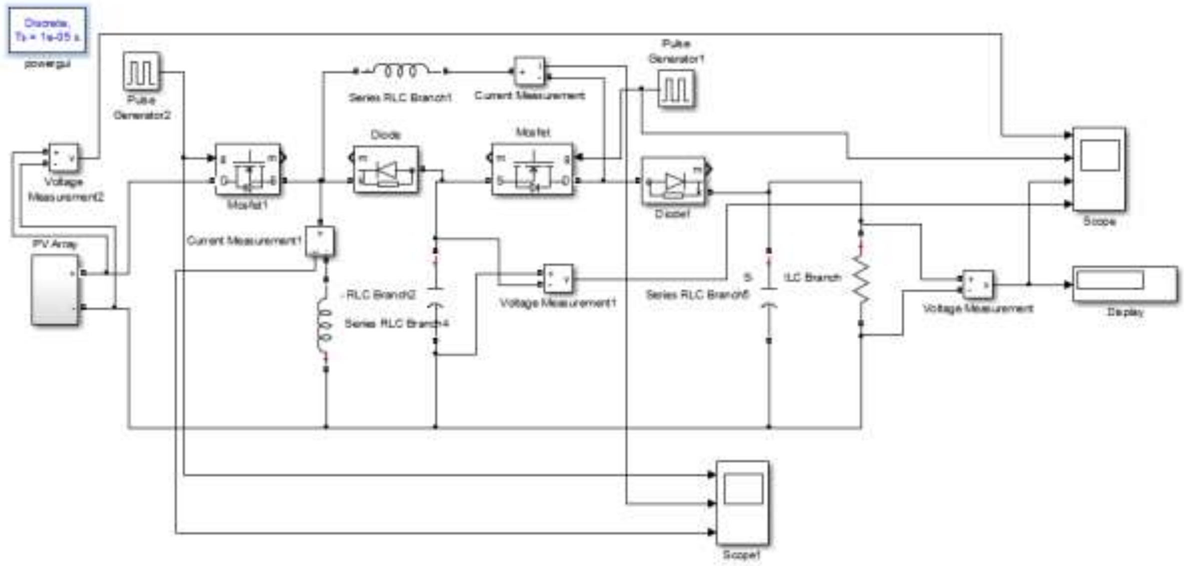

Fig5:Simulation circuit of transformer less Buck Boost converter for solar energy application

b) Simulation Results

The simulation results of the new transformer less buck boost converter with feedback for a solar energy application are shown below. Fig6 represents the time domain waveforms of the DC voltage from pv array converter driving signal voltage, voltage across the capacitor and output voltage under the duty cycle of 0.6 in step up mode

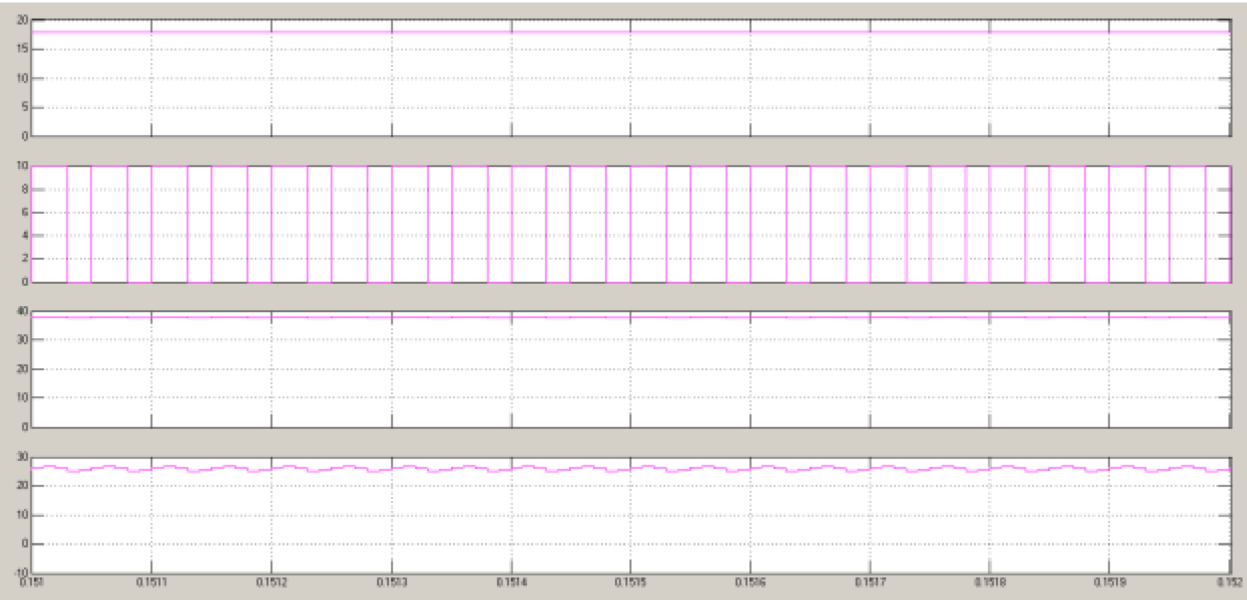

Fig 6: Simulation results of the converter operating in step up mode

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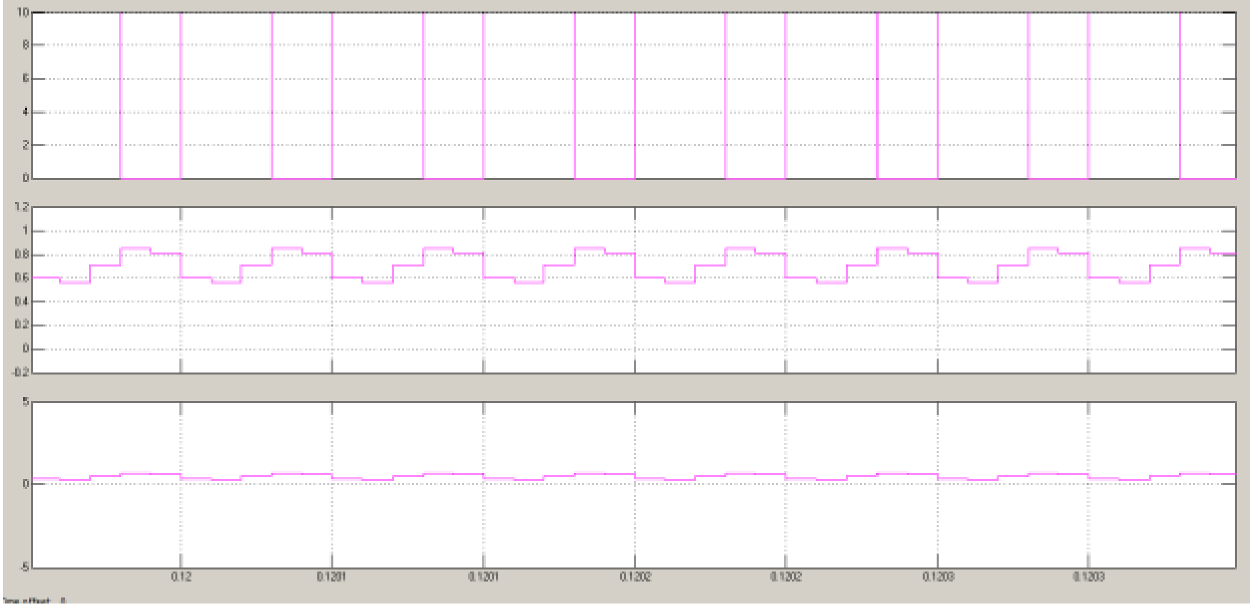

Fig 7: Simulation result of the converter operating in step up mode

Fig 7 shows the time domain waveforms of the driving signal (Vg),and the currents through the two inductors L1,L2 operating in the step up mode when the duty cycle is 0.6

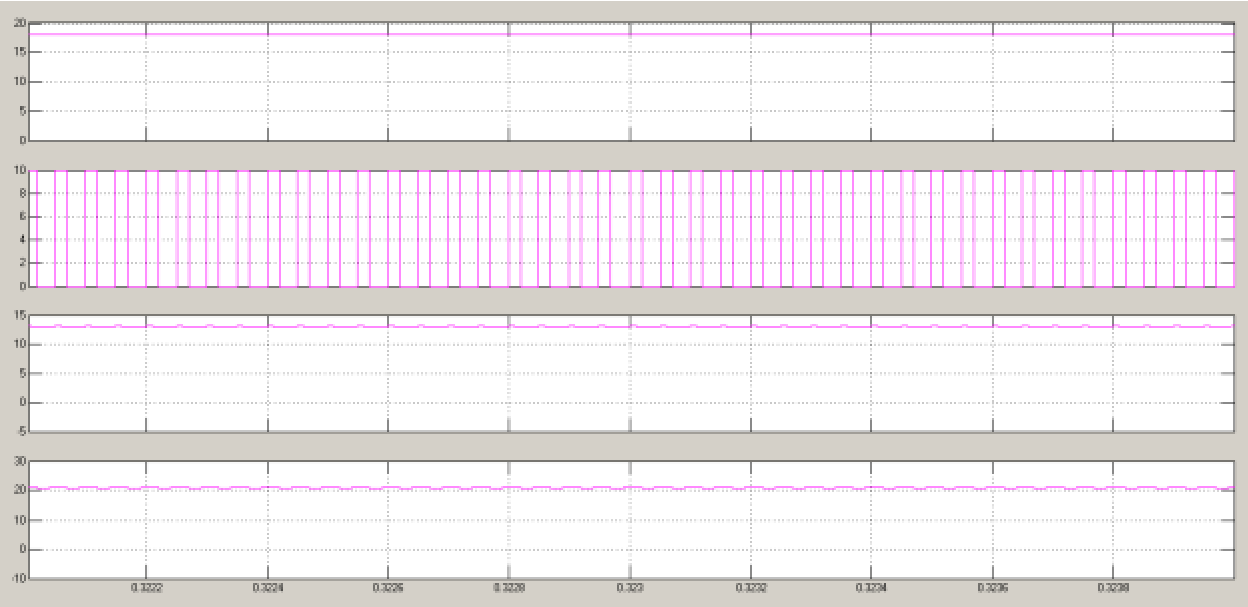

Fig 8:Simulation result of the converter operating in step down mode

From the design equations[1] the theoretical results are for step up mode:
V_{C1}=27V, V_{OUT}=40.5V, I_{L1}=0.34A,I_{L2}=0.68A,

For step down mode
V_{C1}=2V,V_{CO}=0.4V,I_{L1}=0.54A,I_{L2}=0.45A, respectively

Fig8 represents the time domain waveforms of the converter DC voltage from pv array driving signal voltage, voltage across the capacitor and output voltage under the duty cycle of 0.4 in step down mode.

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Fig 9: Simulation result of the converter operating in step down mode

Fig 9 shows the time domain waveforms of the driving signal (Vg), and the currents through the two inductors L1,L2 operating in the step down mode when the duty cycle is 0.4

IV. CONCLUSION

The new Transformer less buck-boost converter with feedback is simulated using Matlaband analyzed. To overcome the demerits of traditional buck boost this converter is proposed by inserting an additional switched network into the traditional buck-boost converter. Transformerless buck-boost converter possesses the merits such as high step-up and step-down voltage gain, positive output voltage, simple construction and simple control strategy. Hence, the proposed transformer less buck-boost converter is suitable for the solar energy application to deal with low voltage pv array and this converter is also suitable for industrial applications requiring high step-up or step-down voltage gain. The converter operates in a wide range of output voltage without using any extreme duty cycles. It provides enough gain within the duty ratio 0.4-0.6.. The proposed converter will not only provide high voltage gain, but also reduce the extremely high duty cycles of power switches, and increase the efficiency of the converter.In order to make the output voltage constant irrespective of load conditions a feedback also can be provided using PI controller and pwm generator to provide driving signal to power swutches.

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