Non Isolated High Voltage Gain DC-DC Converter with PI Controller

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***Abstract*— DC-DC converters are widely used in applications such as power supplies for electronic devices, Renewable energy system, electric Vehicles etc. DC-DC converters are classified into different types based on the topologies used for voltage conversion. In this article a non-isolated DC to DC boost converter having high voltage gain for voltage sources with low input is created which enable the use of PI Controller for improved performance of the whole system. Here a two-inductor boost converter was combined with a voltage multiplier, switched capacitor cells to make a high-voltage-gain dc-dc converter. The Proposed converter have high voltage gain, simplicity of operation, lower voltage, and lower current stresses on the components. . There are constant voltage variations for converters' outputs as a consequence of changes at the load and source end. In order to achieve a constant output voltage regardless of the source or load change, proportional integral controller is also employed in the proposed system.**

***Index Terms*— Boost converter, dc–dc converter, high voltage gain, hybrid, transformerless, PI controller.**

I. INTRODUCTION

The standard DC- DC boost converter is one of the non-isolated converter which is used to step up the low input voltage. This circuit has several features like simple structure, high stability characteristics etc which make it suitable for many applications. Along with these features it has some shortcomings like low efficiency, low voltage gain. In order to achieve more efficient performance, as well as to get increased converter voltage gain, large variation of duty cycle is required. This leads to a high voltage stress in the semiconductor, problems with diode reverse recovery and excessive switching losses which decreases the system efficiency and performance. So the major challenge is to improve the gain of DC to DC converter at low duty cycle.

Different techniques are there to boost the output voltage of Boost Converter. Some of them are Voltage Multiplier, switched capacitor, coupled inductor etc. By considering the features and short comings of various technique a high gain DC-DC converter is proposed in this article.

The proposed DC-DC boost converter is a combination of two inductor converter with voltage multiplier and switched capacitor. The proposed system is also implemented with proportional integral controller, in order to get a constant output voltage irrespective of the change in load and source voltage. By this way converter attains high gain with reduced stress across its components.

II. COMPARISON BETWEEN EXISTING AND PROPOSED SYSTEM

A. The main difference between the existing system and proposed system is that here high gain can be achieved without having large variation in duty cycle
B. The proposed converter is a combination of the a voltage multiplier cell and a switched capacitor cell. This way, the converter achieves high efficiency with low voltage and current stress across the components than the existing system.
C. Inorder to prevent unbalanced voltage stress across inductor, approaches are made to increase the number of switches in the circuit. But this requires more gate drive circuits which increases the complexity of circuit. So in this system high gain is achieved without increasing the no of switches
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III. OBJECTIVES

A .The main objective of the project is to implement a high voltage gain DC-DC boost converter for voltage sources with low inputs

B. To reduce the voltage stress across the semiconductor components

C. To use Proportional Integral controller for controlling the output of the DC-DC converter

IV. PROPOSED SYSTEM

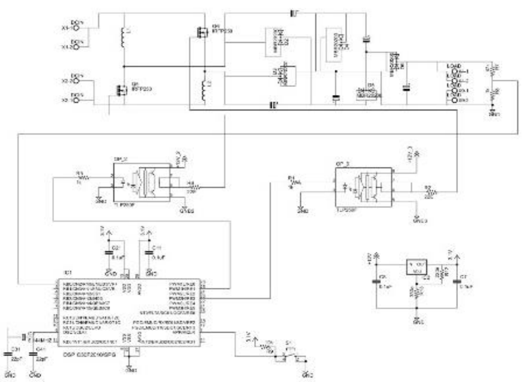


Fig 1 Circuit diagram for proposed system

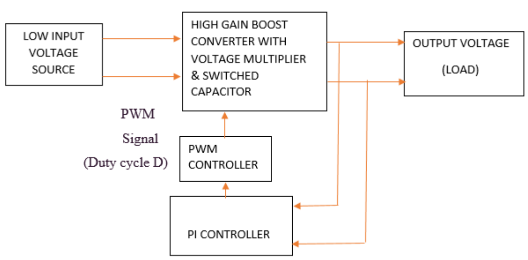


Fig 2 Block diagram of proposed System

There are five blocks in the system. A low input voltage source, High gain boost converter with voltage multiplier and switched capacitor, Pulse width modulator, PI controller and Resistive load.

A. High gain DC-DC Boost converter with voltage multiplier and switched capacitor

In order to increase the voltage gain with reduced voltage and current stress across the components, the proposed converter employs the use of voltage multiplier and switched capacitor .The circuit consists of two switches(S_1, S_2), two inductors ($L_1$and L_2), five Diodes (D_1, D_2, D_3 , $D_{4,} D_0$), and five capacitors (C_1, C_2, C_3 C_4, and Co). The position of the components are important to decrease their current and voltage stress, increase their voltage gain, and also to obtain the simplicity of operation. The converter is designed to operate in continuous conduction mode.

The operation of the converter is divided into two modes. The circuit and wave forms are shown below.

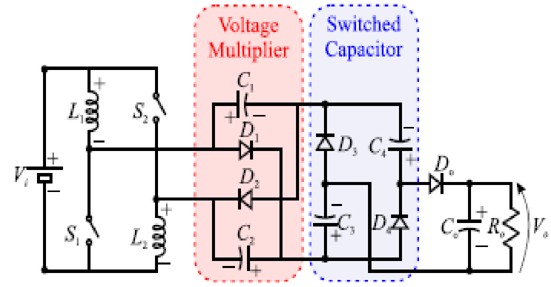


Fig 3 DC-DC boost converter with voltage multiplier and switched capacitor

MODE-1 (t_0 –t_1)

In this mode the switches S_1 and S_2 are turned ON simultaneously. At that time inductor L_1 and L_2 are magnetized.. Inductor current rises linearly during this time interval. Diodes D_1 , D_2 , D_0 are reverse biased and D_3 & D_4 are forward biased. CapacitorC_1, C_2 releases its energy to C_3 and C_4 and the output capacitor C_0 releases its energy to load resistor R. The equations corresponding to this mode of operations are

$$VL_1 = VL_2 = V_i$$

Capacitors C_3 and C_4 are charged up to $V_i + VC_1 + VC_2$.

ie, $VC_3 = VC_4 = V_i + VC_1 + VC_2$

$IS_1 = IS_2 = IL_1 + IC_1$, Where V_i,VL_1 , VL_2 , VC_1, VC_2 , VC_3 , VC_4 , IS_1 and IS_2 are denoted to input voltage, Inductor L_1 voltage, Inductor L_2 voltage, Capacitor C_1 voltage, Capacitor C_2 voltage, Capacitor C_3 voltage ,Capacitor C_4 voltage and current through the switches.

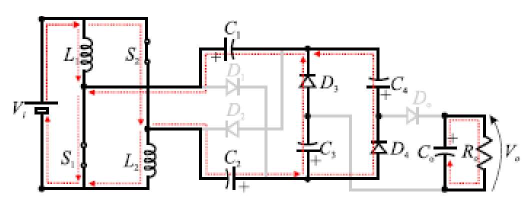


Fig 4 Mode-1 operation of converter

MODE-2(t1-t2)

In mode-2 both the switches are turned off simultaneously. Both the inductor get demagnetized and their voltages are given by $V_i - VC_2$ & $V_i - VC_1$.The diodes D_1, and D_2 of voltage multiplier cell are forward biased in order to provide a continuous path for inductor current. In this mode the source voltage, Inductor L_1, L_2 are connected in series with the capacitor C_1 and C_2.. Capacitors C_1 and C_2 are charged during this time interval.. Diodes D3 and D4 are reverse biased and C_3 and C_4 are discharging in output capacitor C0.The diode D_0 is forward biased and the output capacitor C0 is charged to $VC_3 + VC_4 - VC_2$

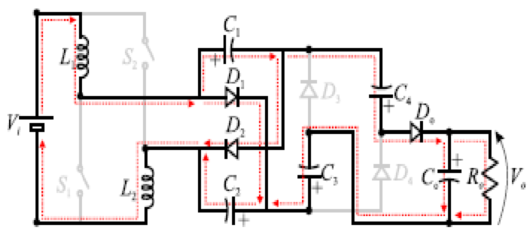
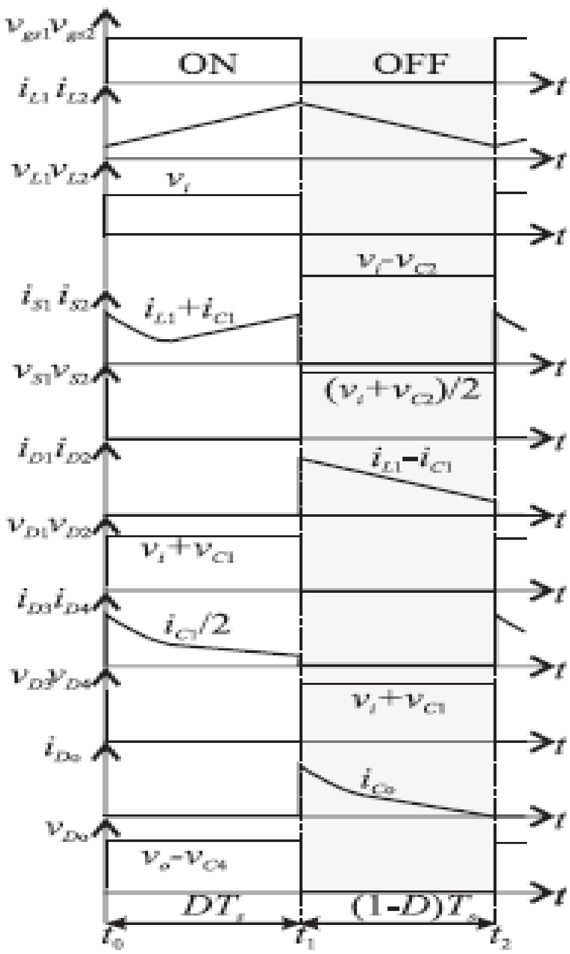


Fig 5 Mode-2 operation of converter



(a)

Fig 6 Wave form

B. VOLTAGE GAIN

To find the static gain of the proposed converter, the volt second balance principle is to be applied to inductor

$$V_i DT_s + (V_{in} - VC_1)(1-D)T_s = 0$$

By simplifying the above equation VC_1 and VC_2 of voltage multiplier cell

$$VC_1 = VC_2 = \left(\frac{1+D}{1-D}\right)V_i$$

In switched capacitor cell

$$VC_3 = VC_4 = \left(\frac{3+D}{1-D}\right)V_i$$

Finally the static gain can be found by evaluating stage 2,

$$V_0 = VC_3 + VC_4 - VC_2$$

There for M is given by

$$\frac{V_0}{Vi} = \left(\frac{5+D}{1-D}\right)$$

C. VOLTAGE STRESS

For the switches voltage stress are given by

$$VS_1 = VS_2 = \left(\frac{V_i}{1-D}\right)$$

For diodes,

$$VD_1 = VD_2 = VD_3 = VD_4 = VD_0 = \frac{2V_i}{1-D}$$

The voltage stress value across all the diodes is same

D. PI CONTROLLER & PWM GENERATOR

Proportional integral controller is employed to attain constant output voltage irrespective of the input. It is formed by combining proportional and integral control action. A PI controller calculates an error as the difference between the measured value and the set value. PI controller improves the steady-state performance of a control system.

A Pulse Width Modulation (PWM) generator is an essential component in a Boost Converter with a PI (Proportional-Integral) controller. The PWM generator produces a series of pulses that control the switch in the Boost Converter. The duty cycle determines the fraction of time that the switch remains on during each switching period. By controlling the duty cycle, the output voltage of the Boost Converter can be regulated.

The PI controller will ensure the boost converter deliver a sufficient amount of voltage to the load

An error signal was generated by comparing the output voltage with the constant input voltage. After that, the error was connected to the PI block and the output was compared to the saw tooth signal to generate an equivalent duty cycle that was used to drive the switching devices of the converter.

V. ADVANTAGES DISADVANTAGES

Advantages

- High voltage gain
- Reduced voltage stress on the components
- Simplicity of operation
- High precision due to addition of the PI controller, which continuously adjust the converters duty cycle to maintain stable output voltage ensuring high precision and accuracy
- Better efficiency
- Fast response
- Flexibility
- Reliability

Disadvantage

Since this converter offer advantages, it also has some disadvantages that needs to be considered

- This converter is non isolated converter, so there is an electrical connection between input and output, for converters powered from high and potentially hazardous voltages, isolation is required.
- The design process involves tuning the PI Controller which can be challenging and time consuming

VI.APPLICATION

High gain boost converter are used in various application where a high voltage level is required. They provide an efficient way to generate high voltage level from a low input voltage

- Can be used in renewable energy system to boost the voltage from solar panel or wind turbines to a level that can be used to charge batteries or feed the grid
- Power supplies for electronic devices
- Can be used in Electric vehicles to boost the voltage from batteries to a level that is required to drive the motor and other electrical component.
- Can be used in telecommunication applications to provide high voltage for various electronic systems.

VII. RESULT AND DISCUSSION

The high gain DC –DC boost converter with PI Controller is simulated in MATLAB/SIMULINK
The Simulink model and waveforms are shown below

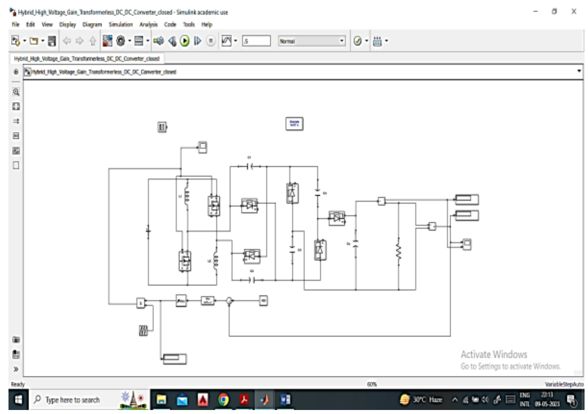


Fig 7 Simulink Model of proposed system

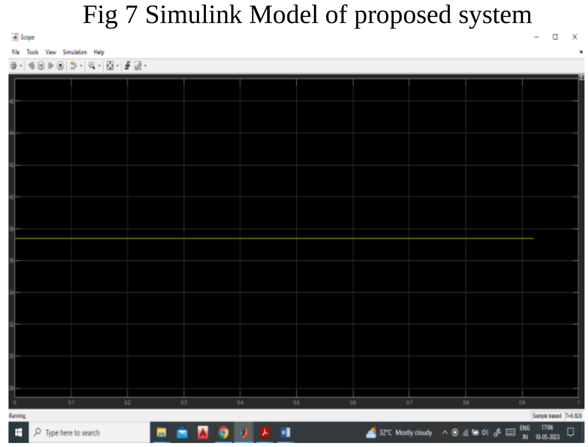


Fig 8 Input Wave form

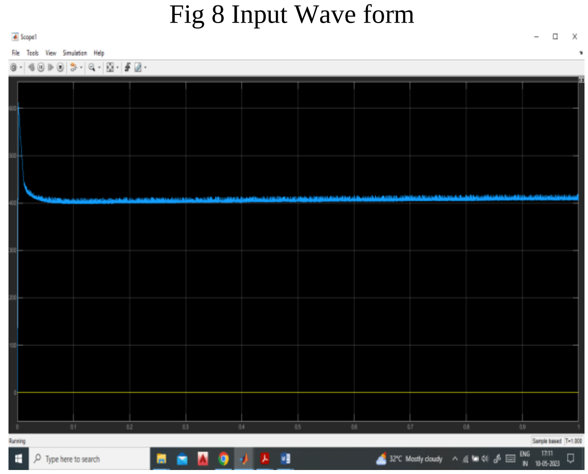


Fig 9 Output Wave Form

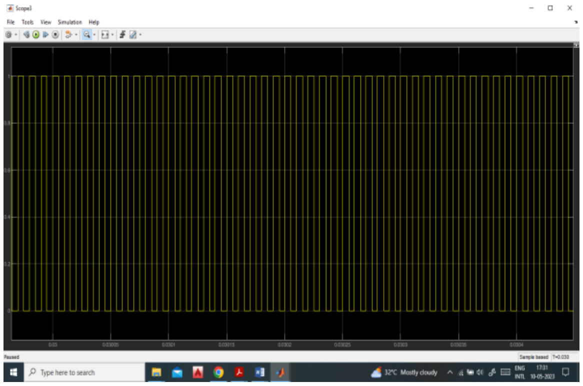


Fig 10 Gate Pulse

VIII.CONCLUSION& FUTURE SCOPE

The purpose of the work was to develop a DC-DC boost converter with PI Controller to get high gain with reduced stress in the components. For that a boost converter with two inductor and two switches is merged with voltage multiplier and switched capacitor cell .The developed system consists of two switches, two inductors and 5 capacitors. The position of these components allows the proposed converter to achieve high gain. In addition to this its operation is very simple. In this, we obtained a gain which is higher than that in two inductor two switch boost converter. PI controller is provided in the system to get a constant constant output voltage regardless of the source or load change. Thus, It is understood that the proposed converter is a strong candidate for high voltage gain applications.

The proposed High gain DC to DC converters with PI controllers have a promising future scope due to their ability to efficiently convert high voltage to low voltage or vice versa, while maintaining a stable output voltage despite variations in the input voltage and load. As the use of renewable energy sources such as solar and wind power increases, the demand for high-efficiency DC to DC converters that can efficiently convert the DC output of these sources to usable AC power will also increase. In future by using advanced semiconductor material we can further improve the efficiency of the system.

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