

**A NEW DC-DC CONVERTER TOPOLOGY FOR RENEWABLE ENERGY
APPLICATION**

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ABSTRACT: *The advancement of technology led to the utilization of electrical energy. Renewable sources like photovoltaic (PV) systems play a vital role in the generation of electricity. But the output voltages of these sources are very low. This paper proposes a soft switching (ZVS) high voltage gain step-up converter for increasing the output voltages of these systems. The proposed system is developed in such a way that the gain of the converter is high, voltage stress across the switches is low and the switching losses are also less. The proposed system is simulated in the MATLAB/SIMULINK environment.*

INDEX TERMS: *High voltage gain, photovoltaic system, soft switching, step-up converter, switching losses, voltage stress.*

INTRODUCTION

Renewable energy systems play a vital role in the generation of electricity. Photovoltaic system is one of the renewable systems. The output voltages of these PV systems are very low. So to connect these renewable systems to the electrical grid this low voltage is not sufficient. Hence these low voltages must be enhanced, by using a step-up DC/DC converter.

A boost converter is used for this purpose. To increase the output voltage to that high value the duty cycle of the converter must be very high i.e. around 0.9. But, it is not possible in general due to the diode reverse recovery problems, and if the converter is operated with high duty cycle the variations in the output is very high, with a slight change in the input.

To overcome this drawback large numbers of PV cells are connected in series but this is not a practical solution. Hence number of proposals has been done for step-up converters.

To overcome this drawback, a large number of large voltage step-up converters have been proposed, as in [1-14]. In [3] and [4], the use of an interleaved boost converter associated with an isolated transformer was introduced, using a high frequency AC link. Despite of the good performance, this topology uses three magnetic cores.

In [5], the converter presents low input current ripple and low voltage stress across the switches. However, high current flows through the series capacitors at high power levels. In [6-8], converters with high static gain based on the boost-fly back topology are introduced, which presents low voltage stress across the switches, but the input current is pulsed, as it needs an LC input filter. The step-up switching-mode converter with high voltage gain using a switched-capacitor circuit was proposed in [9]. This idea is only adequate for low power converters as it results in a high voltage stress across the switches and many capacitors are necessary.

In [10-12] the three-state switching cell is shown. In [12] a voltage doubler rectifier is employed as the output stage of an interleaved boost converter with coupled inductors. In [13] the converter has some advantages compared to the others: possibility to operate in large voltage range, high efficiency, and high power capability. It can be seen in [13] that the number of semiconductor devices is the same as in the traditional interleaved boost arrangement, though two coupled inductors L1 and L2 are added, resulting in higher output voltage. The main drawback of this topology is the hard switching mode, which causes power losses.

The structure presented in [14] is an alternative of [13], in which a commutation cell is associated to the main topology in order to reduce the current stress on the switches. Despite of achieving higher efficiency, this solution leads to a more complex control and structure, due to the presence of an extra auxiliary circuit for each switch. Nevertheless, most of solutions include different stages to perform battery charging and step up goals.

This paper presents a soft switching boost converter integrated in such a way that the battery charging stage, high voltage step-up stage, and the photovoltaic stage are obtained in a single stage conversion.

PROPOSED CONCEPT

The circuit diagram of the proposed system is as shown in figure.1.

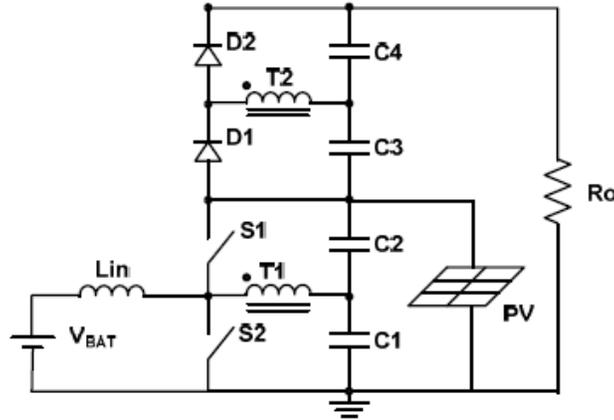


Fig.1.Proposed system using PV system

Compared to the conventional boost converter, proposed system has an extra transformer and four capacitors are present by which soft switching can be obtained.

BLOCK DIAGRAM REPRESENTATION

The block diagram representation of the conventional and the proposed PV system are as shown in figure.2 and figure.3 respectively.

The complexity of the circuit in conventional system is high compared to the PV system with proposed high gain boost converter. Hence the switching losses and the voltage stress across the switches are less compared to the conventional system.

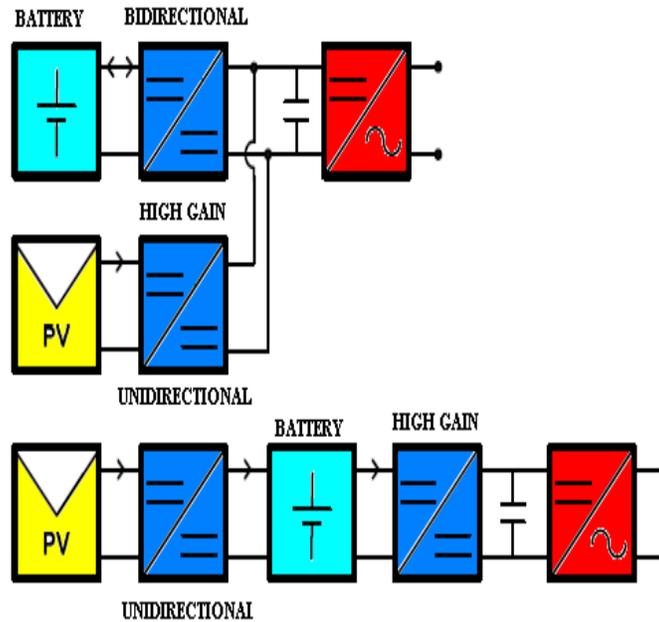


Fig.2.Conventional PV system

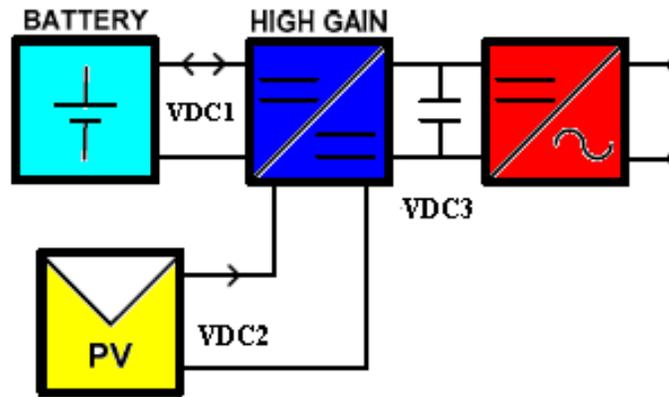


Fig.3.Proposed PV system

PRINCIPLE OF OPERATION

The operation of the proposed high gain step-up converter is explained as follows. For simplicity the input voltage and the output current are considered as ripple free.

Operation of the converter in a cycle can be divided into four modes. These are explained as follows,

Mode-1

This mode is valid from (t_0-t_1) . In this mode switch S1 is off and the switch S2 is on. In this mode the difference between the transformer leakage current and the input current flows through the anti parallel diode of the switch S2 and decreases linearly and finally becomes zero at the end of stage. The circuit diagram representing this stage is as shown in figure.4.

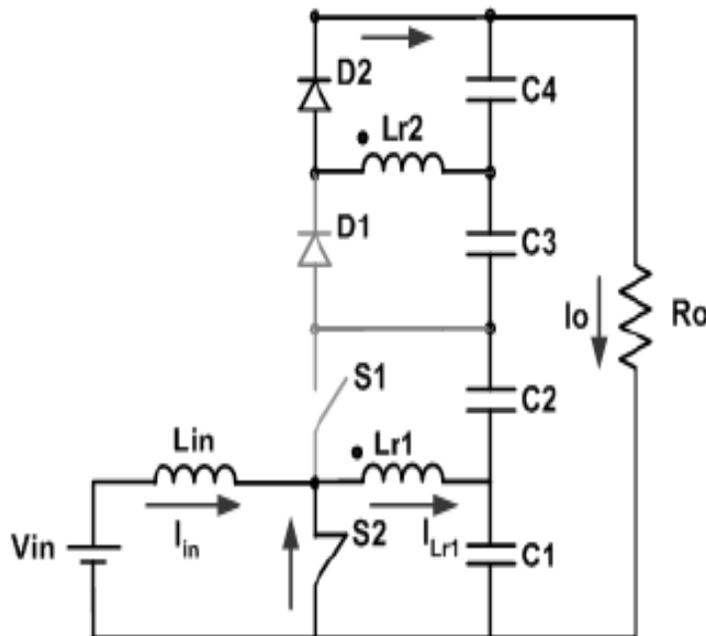


Fig.4.Mode-1(t_0-t_1)

Mode-2

This mode is valid from (t_1-t_2) . In this mode sum of the input current and the primary current are conducted through the switch S2. C3 gets charged through secondary of the transformer. The circuit representing the mode-2 is shown in figure.5.

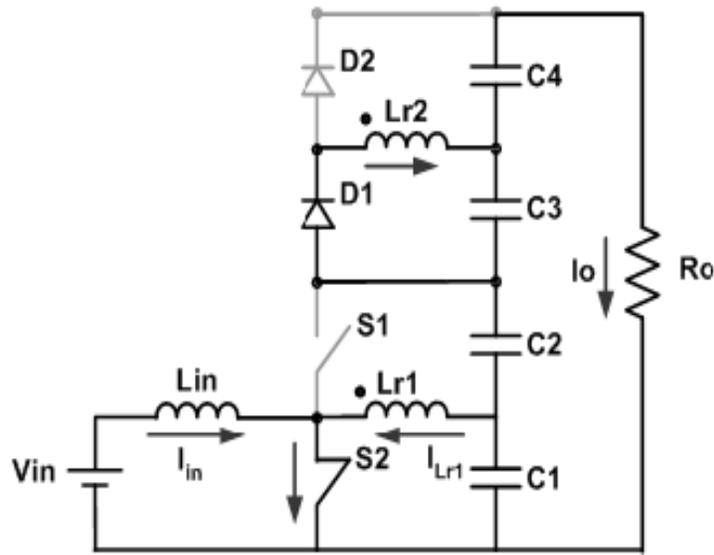


Fig.5.Mode-2(t_1-t_2)

Mode-3

This mode is operated from (t_2-t_3). In this stage switch S2 is off and the switch S1 is turn On. The current that flows through S1 is the sum of the input current and the one through the transformer primary side, and increases linearly. This stage ends when the current on the primary reaches zero. The circuit diagram representing the mode -3 is as shown in figure.6. capacitors C2 and C3 gets charged in this stage and is as shown below figure.6.

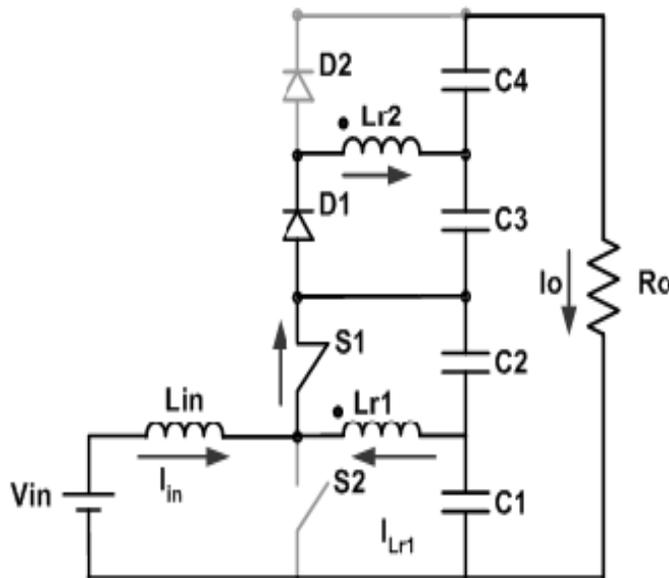


Fig.6.Mode-3(t_2-t_3)

Mode-4

This mode is valid from (t_3-t_4). In this mode switch S1 is on and switch S2 is off. In this mode the sum of input current and the capacitor C2 current flows through the transformer primary side. This stage ends when S2 turns on and S1 turns off. The circuit representing this mode is as shown in figure.7.

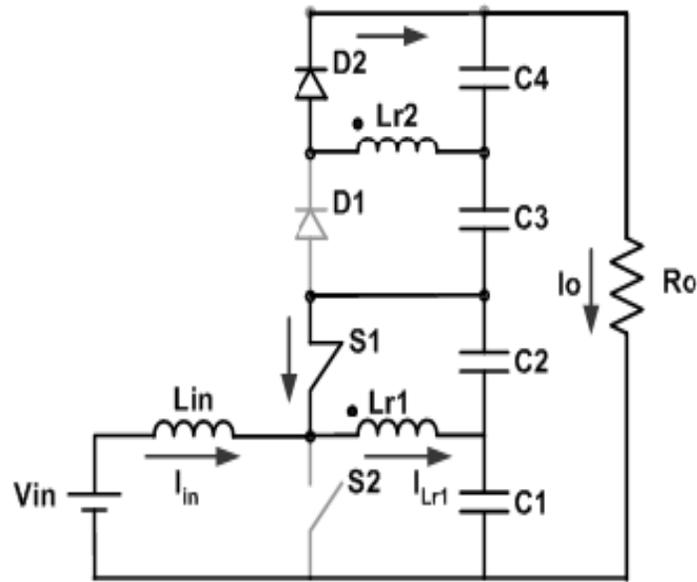


Fig.7.Mode-4(t_3-t_4)

VOLTAGE GAIN

The output of the proposed system is the sum of the voltages across the individual capacitor. i.e.

$$V_0 = V_{C1} + V_{C2} + V_{C3} + V_{C4} \quad (1)$$

Where the voltage across the capacitors are given as below.

Voltage across capacitor C1 is

$$V_{C1} = V_{in} \quad (2)$$

Voltage across capacitor C3 is

$$V_{C3} = nV_{in} \quad (3)$$

Voltage across capacitor C2 is

$$V_{C2} = \frac{DV_{in}}{1-D} \quad (4)$$

Voltage across capacitor C4 is

$$V_{C4} = n \frac{DV_{in}}{1-D} \quad (5)$$

The total output voltage is

$$V_0 = V_{in} \frac{1+n}{1-D} \quad (6)$$

The voltage gain of the proposed converter is given as

$$G = \frac{V_0}{V_{in}} = \frac{1+n}{1-D} \quad (7)$$

Compared to the gain of conventional boost converter the proposed converter has an additional factor of (1+n). Where 'n' is the turns ratio of the converter.

Thus the gain of the proposed system depends on the transformer turns ratio. The relation between the gain of the converter 'G' and the duty cycle 'D' for different values of 'n' is as shown in figure.8.

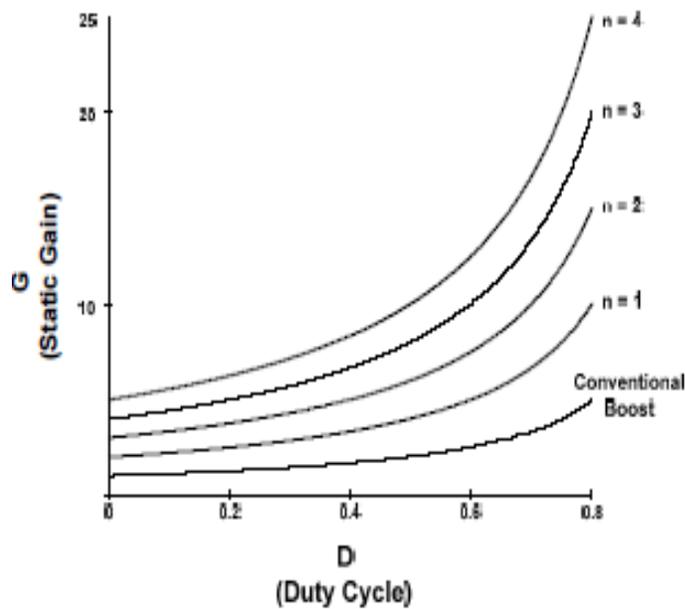


Fig.8.G×D for different 'n' values

THEORETICAL WAVE FORMS

The theoretical wave forms for the proposed converter is as shown in figure.9.

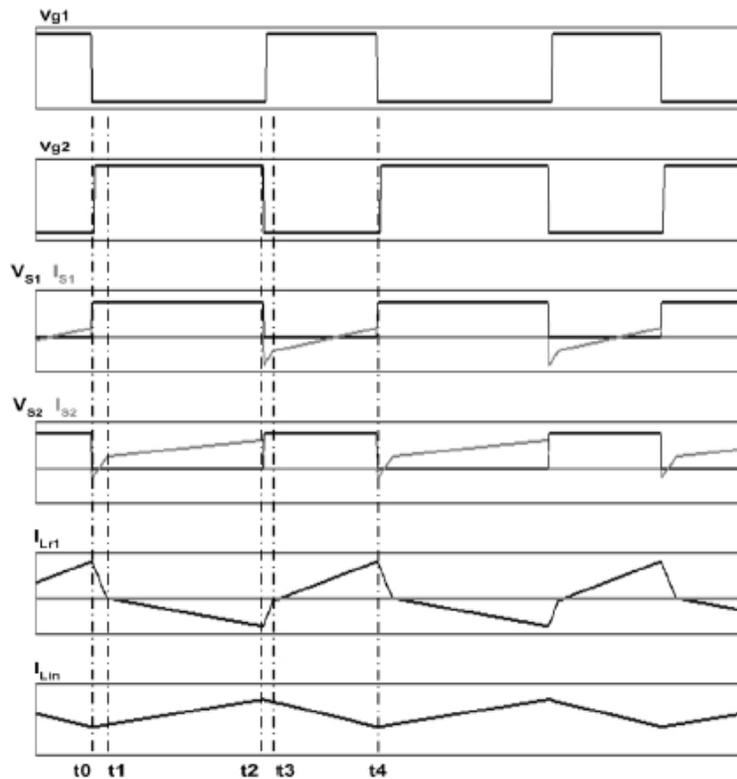


Fig.9.Theoretical wave forms

SIMULATION RESULTS

The SIMULINK model of conventional PV system is as shown in figure.10.

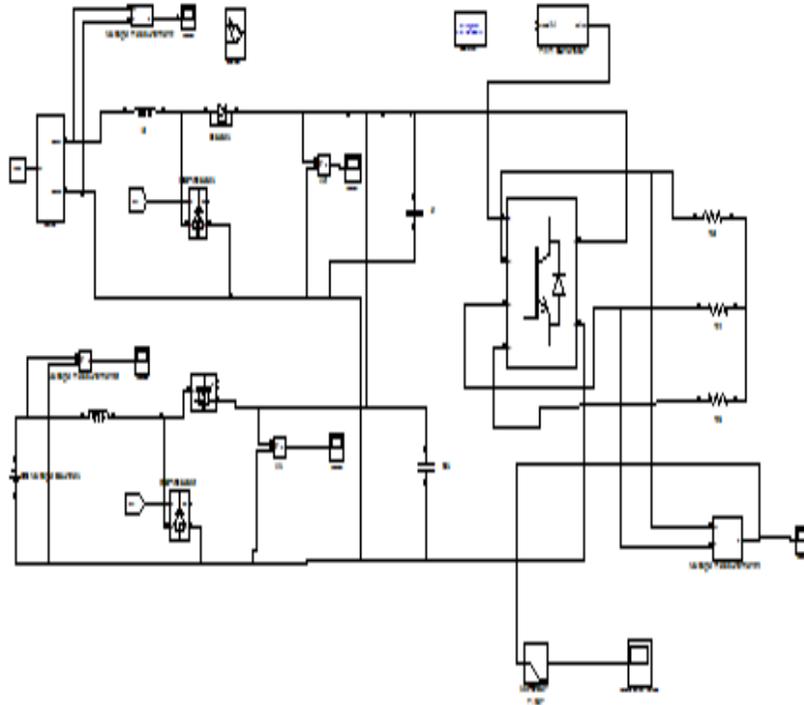


Fig.10.SIMULINK model of the conventional PV system

The output waveform for the conventional PV system is as shown in figure.11.

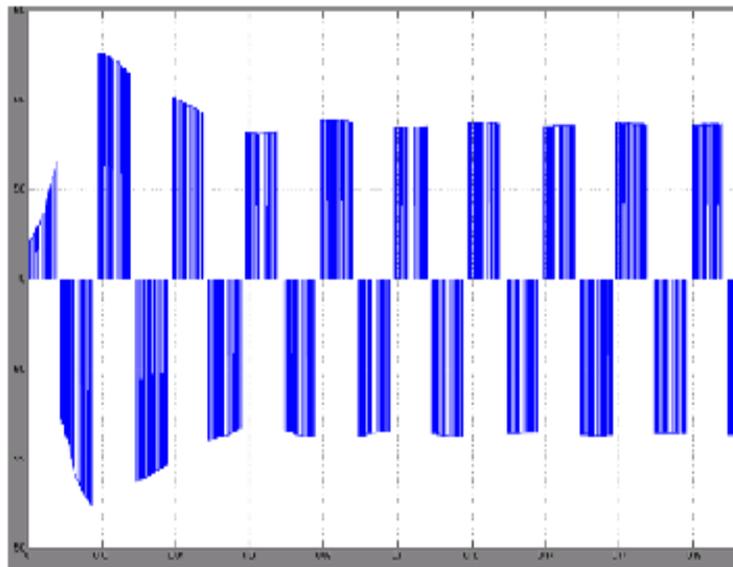


Fig.11.PWm output of conventional system

SIMULINK model of the proposed system is as shown in figure.12.

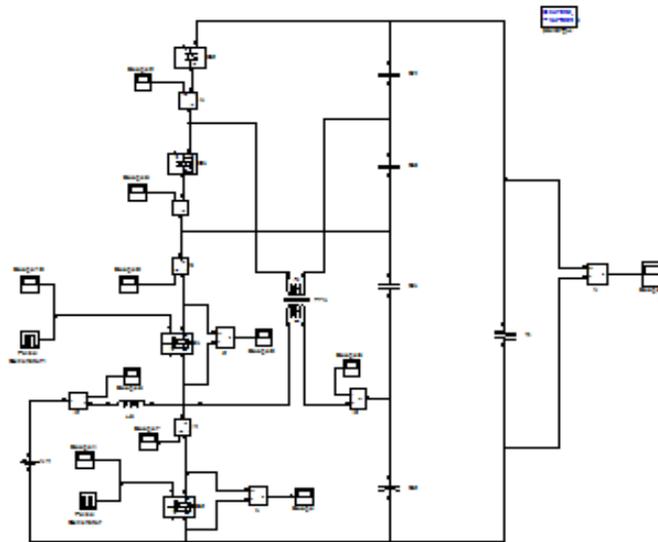


Fig.12.SIMULINK model of proposed converter

The output of the proposed converter is as shown in figure.13.

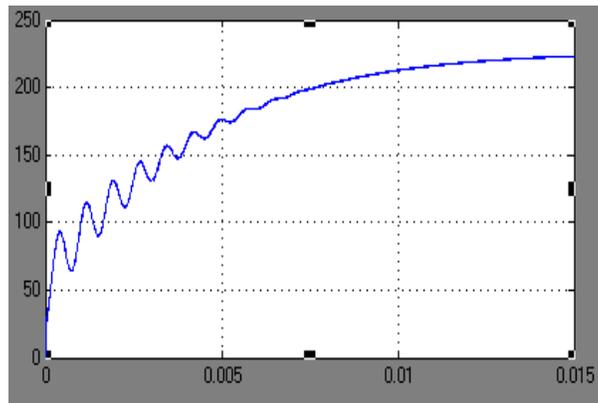


Fig.13.Output of Proposed converter

SIMULINK model of the proposed converter connected to a grid system is as shown in figure.14.

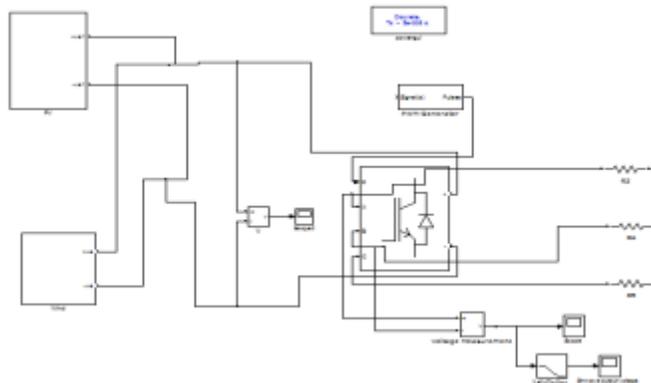


Fig.14.SIMULINK model of proposed system connected to grid

Output of the grid connected system is as shown figure.15.

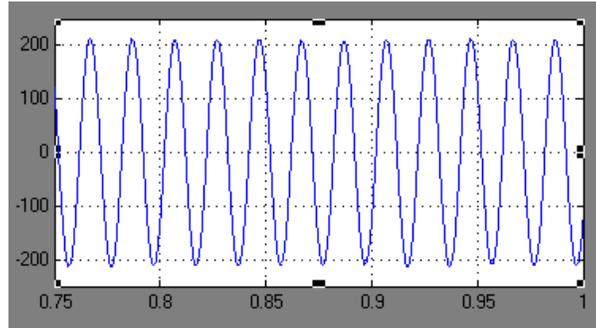


Fig.15.Sinusoidal output of Grid connected system

CONCLUSION

A boost converter with high voltage gain was presented in this paper. Its equations, operation principle, and main theoretical waveforms were all detailed. The topology presents, as main feature, a large voltage step-up with reduced voltage stress across the main switches, important when employed in grid connected systems based on battery storage, like renewable energy systems.

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