Improved High Voltage Gain Converter with Voltage Multiplier Module for Photo Voltaic Applications with MPPT Control

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ABSTRACT— ***This paper focuses on the latest development of modeling and simulation of the grid connected photovoltaic energy conversion system. The paper presents a closed loop high step up high voltage gain converter with a output voltage multiplier module for the photovoltaic application. Solar panel circuit can effectively extract maximum solar power from PV panel using maximum power point tracking technique. Modeling includes the modeling of SPV array, P & O MPPT block, Power electronics converter, inverter in the MATLAB/SIMULINK. The paper also discusses the power connection to the grid.***

Keywords— Boost fly back converter, Grid Connection, Modeling and Simulation, Maximum Power Point Tracking, Photovoltaic Energy, P & O Method

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1. INTRODUCTION

From among the different renewable energy resources, the energy developed due to the photovoltaic effects is always considered as the most essential and sustainable resource. This is due to the sustainability of the abundant solar energy delivered by the sun. Today Photovoltaic energy is considered to be in the forefront in renewable electric power generation. For converting the sunlight into electricity a photovoltaic system can be used. A PV cell is the basic element of a photovoltaic system. Different PV cells can be grouped together to form large PV arrays and these arrays can be grouped and thus different PV systems can be formed. The electricity developed at the output terminals of the PV systems will be very small so that they can feed only small loads. Therefore they require electronic converters for stepping up the developed energy from the PV systems. Different DC-DC converters are available today such as boost converters, fly-back converters, forward converters, etc. Different studies are made in the processing of electricity from the PV devices using various converters[1],[2],[3].

Irradiance and temperature are the two main factors which the power delivered by a PV system depends on. And the power delivered by the PV cells depends also on the current drawn from the cells. Therefore in these systems, maximum power point tracking technique is used to obtain the maximum power available. MPPT is an electronic tracking method of system which changes the electrical operating points of the PV modules, so that it can deliver maximum available power. Perturb & Observe method, Incremental Conductance method, etc., are the different MPPT techniques mainly used.

In all the conventional methods, conventional converters with limited gain and conversion ratio are used for stepping up the dc generated from the photovoltaic modules. These converters produces only limited output voltage which needs to be boosted up again for other applications or grid connected usages.

In this paper the photovoltaic energy developed using the PV module is stepped up by using a boost flyback forward converter. This converter with closed loop boosts up the voltage to a high value which can be then inverted and can be connected to the grid. It is an interleaved boost converter integrated with a output voltage multiplying module. The module consists of switched capacitors and coupled inductors. These coupled inductors are designed to improve the high step-up gain, and the switched capacitors gives high voltage conversion ratio. And when one of the two converter switches turns off, the stored energy in the magnetizing inductor will transfer through three different paths. Therefore the current distribution not only reduces the conduction losses by lowering the effective current but also makes currents through some diodes decrease to zero before they turns off. Also the maximum power is tracked from the PV panels by using Perturb & Observe method of MPPT. Here in this method, P & O searches for the maximum power point by changing the PV voltage or current and detecting the change in PV power output.

2. SYSTEM DESCRIPTION

Figure shows the block diagram of the proposed system.System mainly consists of a PV panel, DC-DC converter, MPPT block, grid connection etc. Photo Voltaic panel produces electrical energy. And this produced energy is then stepped up by using a dc-dc converter. The voltage and current from the PV panel is sensed by the MPPT block and then its output is then used for controlling the switches of the dc-dc converter. The stepped up voltage is then given as input to the inverter. The inverted output is then connected to the grid.

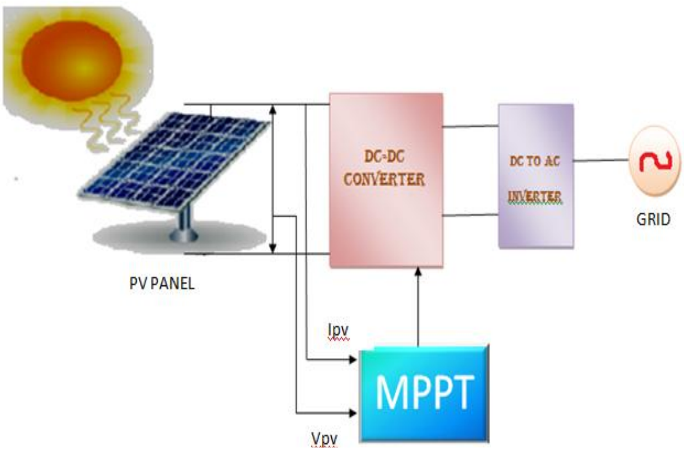


Figure.1.Basic block diagram of the system

The complete system consists of four main parts.

- PV Module
- Interleaved Boost Flyback Converter
- Maximum Power Point Tracking
- Inverter
- Grid Connection

2.1. PV Module

Photovoltaic cell is the basic element of a photovoltaic system. Cells are grouped to form modules or panels. Large photovoltaic arrays can be formed by grouping Panels. The term array is commonly employed in order explain a photovoltaic panel or a group of panels. Every time all of us are interested in modeling the photovoltaic arrays, panels, etc; which are the most commercial photovoltaic devices. Here the paper mainly focuses on modeling of photovoltaic modules or panels composed of several basic cells. An array therefore means any photovoltaic system composed of different basic cells. The electricity developed in a photovoltaic array can directly feed some small loads such as DC motors and lighting systems, etc; Most of the applications necessarily require dc-dc converters to step up the developed electricity from the photovoltaic device. These converters may be employed to regulate the current and voltage at the load, to regulate the power flow control in grid connected systems and to track the maximum available power point (MPP) of the PV device. These arrays present a non-linear current-voltage characteristics. The mathematical model of the photovoltaic array is useful in the analysis of the dynamic study of converters, in the study of maximum power point tracking (MPPT) algorithms and also to simulate the photovoltaic system and its elements using circuit simulators.The equivalent circuit of an ideal photovoltaiccell, which is the basic element of the PV system is shown below.

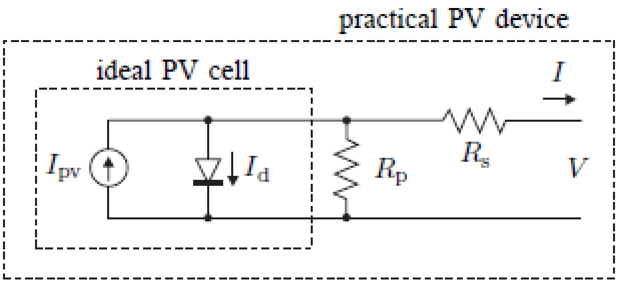


Figure.2. An Ideal photovoltaic cell

The basic equation which mathematically describes the I-V characteristics of an ideal photovoltaic cell from the theory of semiconductors described as in [4] is:

$$I = I_{pv,cell} - I_{o,cell} [\exp(qV/akT)-1] \qquad (1)$$

Where Ipv, cell is the current developed due to the incident light (it is directly proportional to the Solar irradiation), Id is the Shockley diode equation, I0,cell [A] is the leakage current of the diode [A], q is the electron charge [1.60217646*10−19C], k is the Boltzmann constant [1.3806503* 10−23J/K], T [K] is the p-n junction temperature, and a denotes the diode ideality constant.

Figure below shows the I-V curve originated from the above equation.

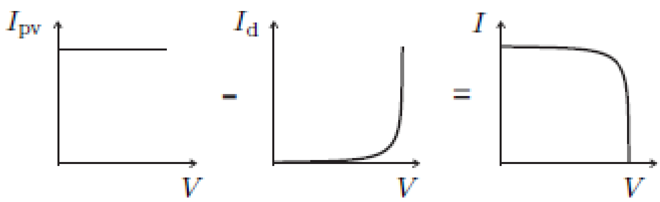


Figure.3. Characteristic I-V Curve of a photovoltaic cell.

Thus I, the net cell current is composed of the light generated current Ipv and the diode current Id.

2.2. Interleaved Boost Flyback Converter

Boost flyback forward converter is developed by combining the operation of interleaved boost, flyback and forward converters. A boost converter is the most commonly used dc-dc power converter whose output voltage is greater than its input. Flyback converters are popular for their simple design for low power applications.A forward converter is another popular switched mode power supply circuit used for developing isolated and controlled dc output voltage from the unregulated dc input supply[3]. The proposed high step boost converter with the voltage multiplier module as in [2], is shown below.

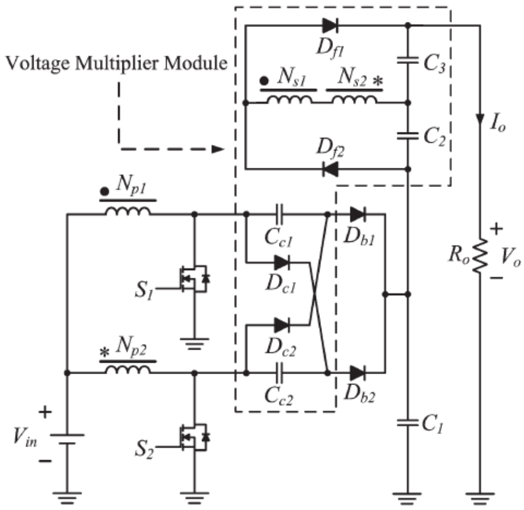


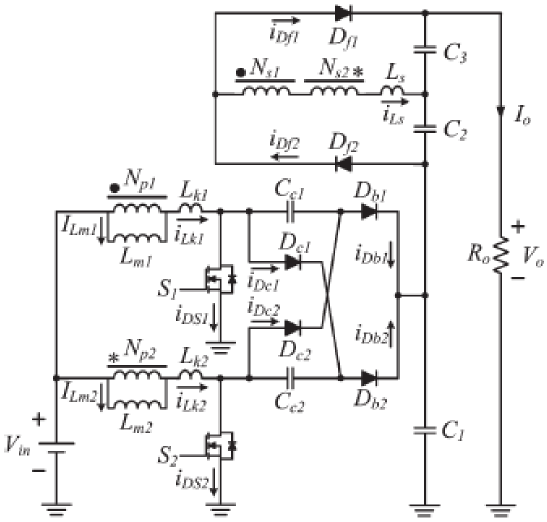
Figure.4. Boost flyback forward converter.

The circuit of the converter consists of a voltage multiplier module which is inserted in between an interleaved boost converter to form a new modified boost flyback forward interleaved structure. Thus the converter is given the name Boost–flyback–forward interleaved converter. Multiplier module is composed of coupled inductors and switched capacitors. Primary winding of the coupled inductors with Np turns are employed to decrease the input current ripple, and also secondary windings of the coupled inductors with Ns turns, connected in series for extending the voltage gain. Analysis of circuits comprising of coupled inductors is done by considering the equivalent circuit of coupled inductors. Therefore the analysis of this converter circuit is done by considering its equivalent diagram as in [2].

Here Lm1 and Lm2 represents the magnetizing inductors; Lk1 and Lk2 are the leakage inductors; Ls denotes the series leakage inductors in the secondary; S1 and S2 represent the power switches; Cc1 and Cc2 denotes the switched capacitors; and C1, C2, and C3 represent the output capacitors. Dc1 and Dc2 are the clamp diodes, Db1 and Db2 are the output diodes for boost operation with switched capacitors, Df1 and Df2 represent the output diodes for flyback–forward operation, and n is defined as turn ratio Ns/Np.In the circuit analysis, the converter operates in the continuous conduction mode (CCM), and the duty cycles of the Mosfet switches during steady state operation are greater than 0.5 and are interleaved with a 180◦ phase shift.

In addition, the voltage gain of the proposed converter is

$$Vo/Vin=(2n+2)/((1-D)) \qquad (2)$$



Figure,5. Equivalent circuit of converter

The equation confirms that the proposed converter has a high step-up voltage gain without an extreme duty cycle. The converter can be modified as a closed loop converter by sensing the output voltage from the converter and comparing it with a reference value. The error is calculated and is minimized by employing a PI controller. The minimized error can be used to produce the switching pulses to the converter along with the MPPT signal.

2.3. Maximum Power Point Tracking

MPPT ie, Maximum Power point Tracking is a complete electronic system that changes the electrical operating point of the modules so that the PV modules can deliver maximum available power. Here in this paper, Perturb and Observe method of maximum power point tracking is employed because of its ease of implementation and popularity. Perturb & Observe method of algorithm is the simplest MPPT algorithm as in [6],[7]. Its implementation and cost is comparatively less. In this algorithm, a small perturbation is introduced in to the whole system. This perturbation can be a small change in voltage. This perturbation results in the change in the power of the solar array. If the perturbation results in increase in power, then it is continued in the same direction. And finally when the maximum power is reached and power change at the MPP is zero and in the next instant it decreases, then the perturbation reverses. One important point is that on reaching very close to the maximum power point, the algorithm doesn't stop, instead it keeps on perturbing on both the directions. P & O searches for the maximum power point by changing the PV voltage & current. The power-voltage curve describing the P & O method is shown in fig.6.

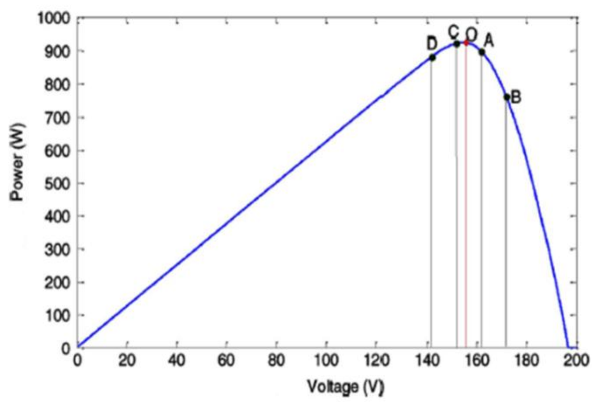


Figure.6. Power Voltage Curve of PV Module

Here in this method, a change in voltage is applied to the system. And then if the powerchange is positive, then perturbation is continued in the same direction. If the change in voltage is positive and resulting change in power is negative, then next perturbation reverses.The flowchart of the P & O algorithm is shown in fig.7.

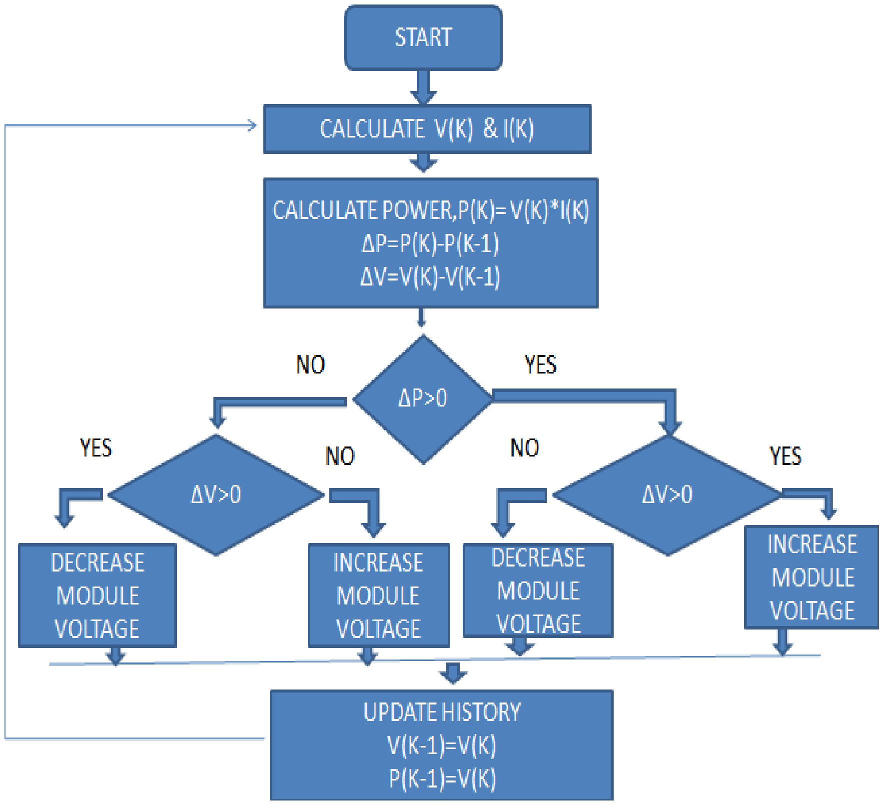


Figure.7. Flowchart of P & O algorithm

The algorithm can be summarized as shown in the table 1.

Table 1. Summarized P & O Algorithm.

PERTURBATON	CHANGE IN POWER	NEXT PERTURBATION
POSITIVE	POSITIVE	POSITIVE
POSITIVE	NEGATIVE	NEGATIVE
NEGATIVE	POSITIVE	NEGATIVE
NEGATIVE	NEGATIVE	POSITIVE

2.4. Inverter

Grid connected inverter is important to couple between the PV and utility system. These inverters must produce good quality sine wave output, must follow the frequency and voltage of the grid. Here a universal bridge inverter is used.

2.5. Grid Connection

The output of inverter is given to a filter in order to reduce ripples and is then given to an isolation transformer. It is then connected to a 230 volt grid.

3.MODELING AND SIMULATION RESULTS

The modeling and simulation of the complete circuit is implemented using MATLAB/SIMULINK software. Modeling includes the modeling of PV circuit, MPPT modeling, converter, etc; The Photo Voltaic Module modeling is as described using (1) in [4],[5],[8]. The simplified simulation diagrams are given here in this paper. The PV module simulation diagram is represented in fig.8.

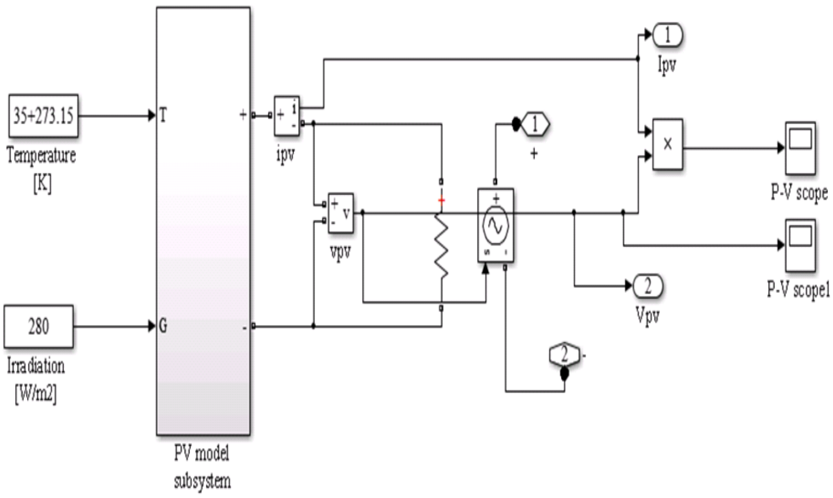


Figure.8. PV Module Simulation Diagram

The PV module output that is applied as input to the converter is given in fig.9.

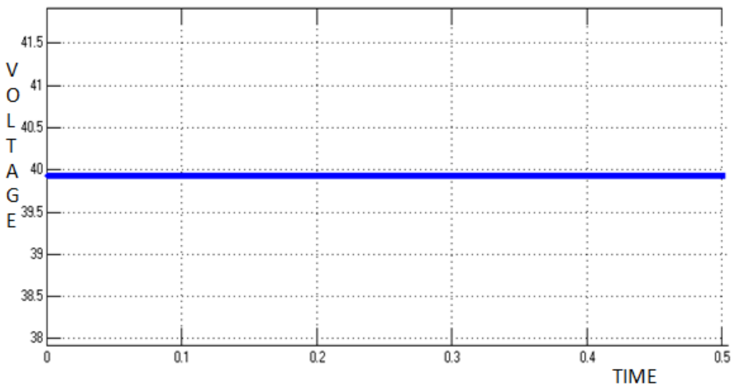


Figure.9. PV Module Output

The Simulink model of the Perturb & Observe MPPT is shown in fig.10.

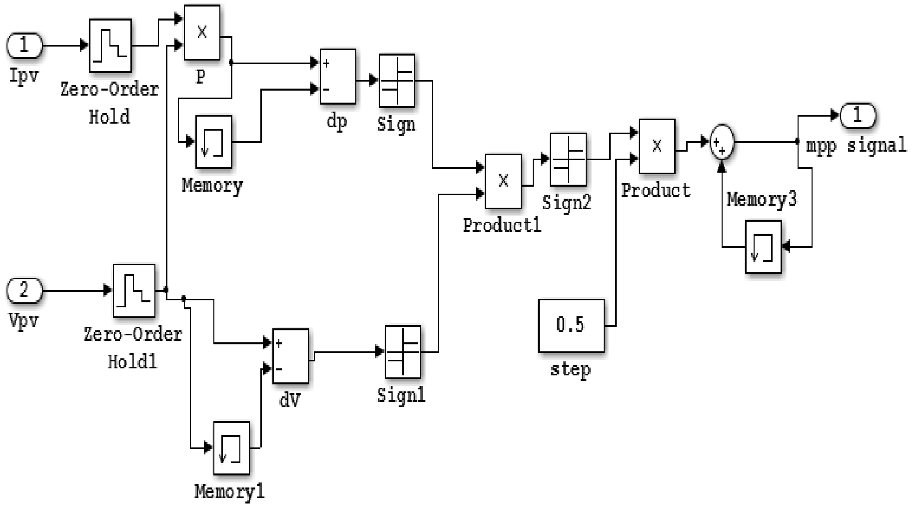


Fig.10. MPPT simulation block

The simulation diagram of the converter with PV module and MPPT block is shown in fig.11

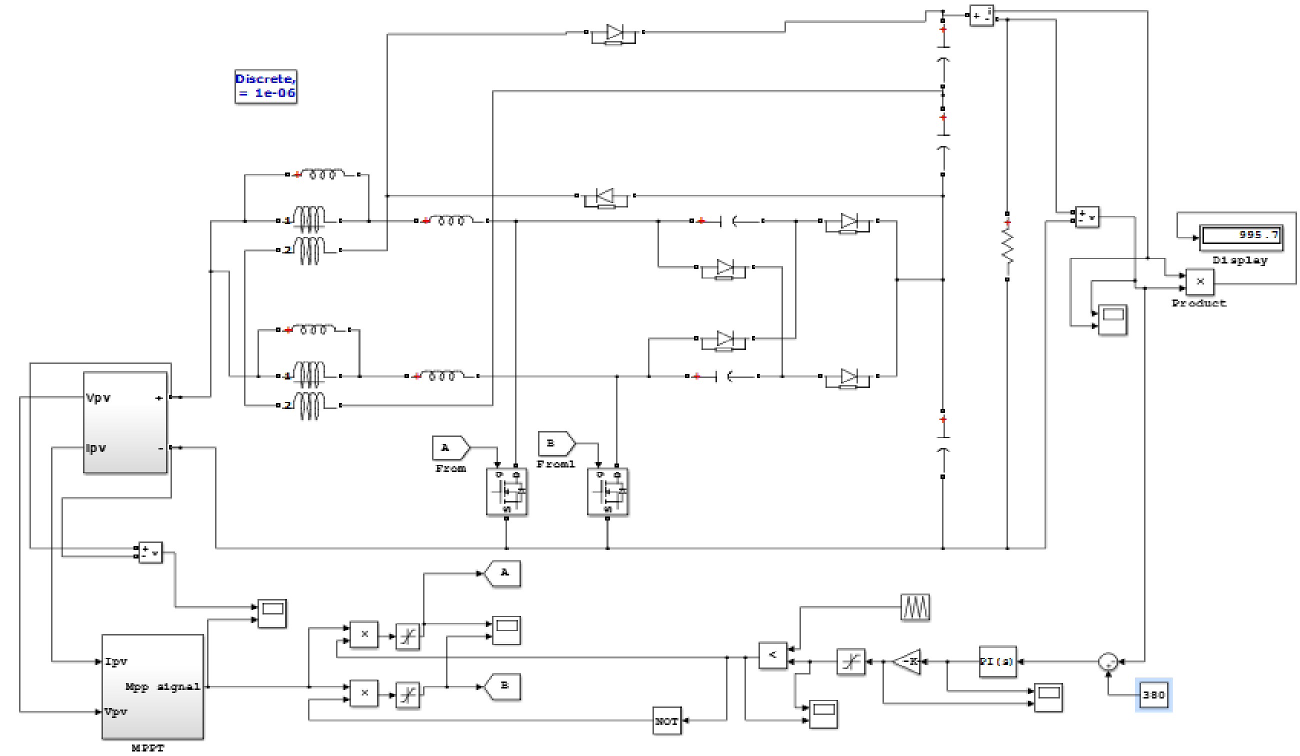


Figure.11.Simulation diagram of the converter

The output voltage stepped by the converter is shown in fig.12.

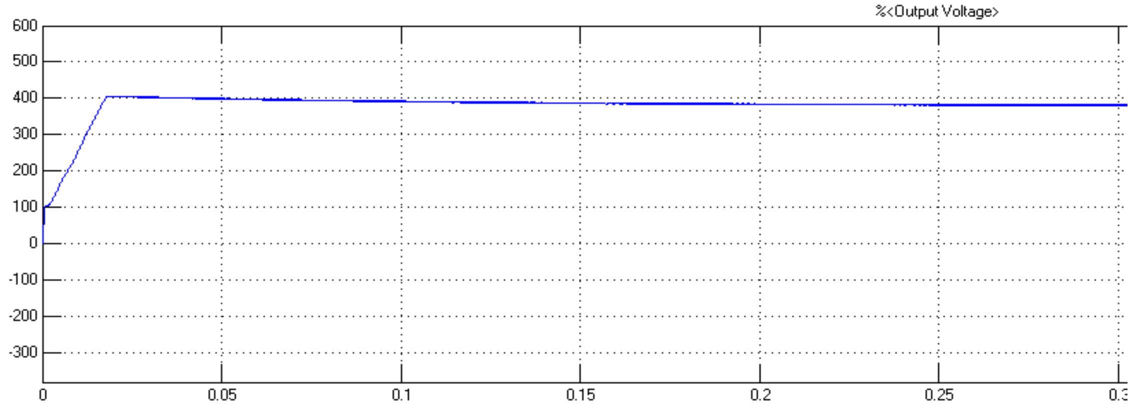


Fig.12. Output Voltage of Converter

The DC-DC converter converts the low voltage from the renewable energy photovoltaic source to high voltage and is given to the inverter. The inverter converts this DC voltage to AC and feeds to the grid.The output voltage obtained from the inverter to be connected to the grid is shown in fig.13.

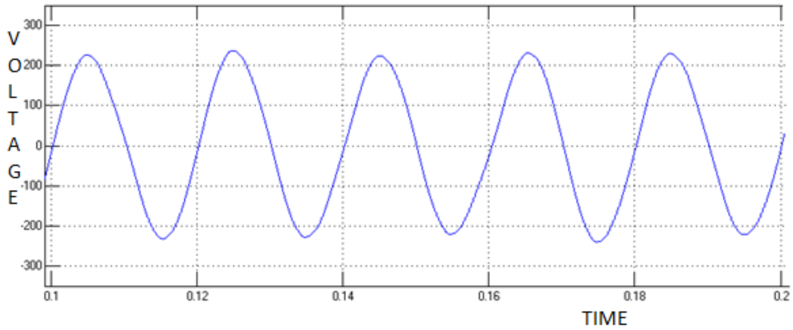


Fig.13. Inverter output voltage

The obtained grid voltage is be shown in fig 14.

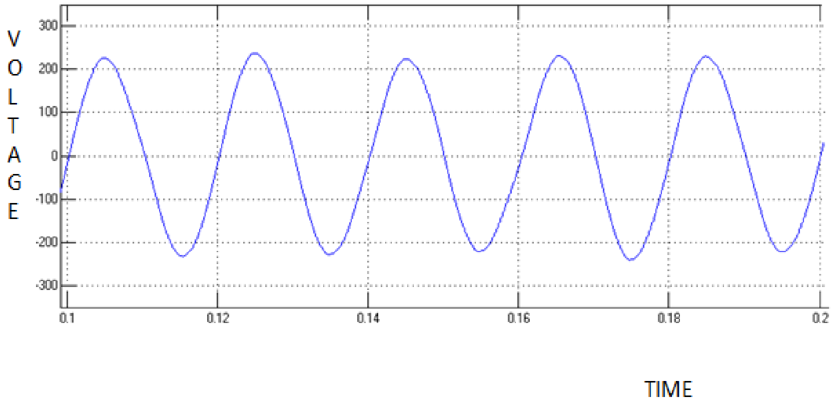


Fig: 14. Grid voltage

4. CONCLUSION

This paper gives an highly efficient PV system with a boost flyback forward converter. It is an efficient high step-up converter with the voltage multiplier module. The interleaved structure reduces the input current ripple and distributes the current through each component. This interleaved converter is developed and simulated in the MATLAB simulink. Through simulation, the converter has successfully proved an efficient high step-up conversion. The output from the converter is then inverted and connected to the grid.

5. ACKNOWLEDGMENT

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