Solar PV Array connected with a single phase PMW inverter with sinusoidal output

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***Abstract*— This paper introduces the matlab simulation design boost converter integrated with single phase PWM controlled DC-AC inverter with an input source as a solar PV system and load as a grid. Boost converter is implemented to boost the solar output . In this paper, single phase inverter is used along with filter to obtain sinusoidal ac from the solar PV array. The boost converter is connected to the solar photovoltaic system to obtain the necessary output voltage from the solar PV array that is to be fed to the grid. The boost converter output can be changed by changing the parameters like resistance. Solar PV array is given a constant irradiation and its output is fed to boost converter. PWM based Single phase inverter is connected to output of boost converter. A LC filter is connected to single phase inverter which gives a Sinusoidal Output. The single-phase inverter with *LC* filter is used to provide a sinusoidal output voltage, regardless of the arbitrary consumer load profiles.**

***Keywords*— *Photovoltaic (PV), Boost Converter, Single phase Inverter, L-C Filter*.**

INTRODUCTION

Electricity demand has been growing continuously due to industrial development, agricultural activities etc., apart from population growth. From many decades, the energy demand has been mainly met by conventional power plants, majorly based on fossil fuels. However, such plants lead to pollution and global warming. Therefore, the renewable energy (RE) based power generation, is encouraged to meet the increased energy demand. Moreover, RE based power sources, are pollution free and abundant in nature. Among these, wind and solar sources, are highly emerging due to their reduced cost and technological advancements.[1][2][3][4] Stand-alone systems based on renewable energy sources are one of the best options for meeting electricity demands in remote and isolated regions where the utility grid is inaccessible or costly [5,6]. These systems, as their name implies, are designed to operate independently of the utility grid. Stand-alone systems are composed of several components that convert the renewable energy sources (such as solar photovoltaic and wind energy) into electric energy in a controlled and reliable manner in order to feed electrical loads. Power electronics in such systems plays an essential role as an enabling technology for a stable and effective stand-alone system control and interface to transfer the extracted power to the loads.Nowadays, renewable energy resources are of great need to society. There are many renewable energy resources available on earth such as wind energy, solar energy, biomass, hydropower, geothermal energy,. Among these, solar energy is the most powerful energy resource and it never runs out. Even though there are some minor drawbacks such as cost-ineffective, inefficient during rainy and cloudy days, it is considered as an extremely beneficial energy resource for the environment. Also, solar energy never runs out, unlikely few other energy resources. There is a strong demand to reduce photovoltaic (PV) energy costs in order to increase the competitiveness and attractiveness of PV plants. Hence, two main challenges must be addressed: better energy conversion efficiency and reduced maintenance costs [7]. The latter can be reduced by increasing the system reliability. The dc-link voltage directly affects the PV inverter power losses.[8] Usually, voltage source inverters are employed in PV systems and a minimum value of vdc is required to inject power into the grid. According to IEC 61727 standard, the PV inverter must remain connected if the grid voltage is between 0.85 and 1.1 pu.[9] Manufacturers generally employ a high fixed dc-link voltage to ensure the inverter suitable operation, injecting rated power into the grid with 10% of overvoltage (worst case)[10]. However, outside this operating condition, there is a considerable margin for vdc manipulation. The operation in the minimum dc-link voltage tends to reduce both semiconductors and capacitor stresses, which is very desirable from the reliability point of view. Most of the solar panels have only 15-20% efficiency. Few high standard solar panels have 22-23% efficiency and no solar panels are existing more than this efficiency. So, it is necessary to use the best algorithm for improved efficiency and more run time. Solar PV array is in demand and decreases the carbon foot-print. Small and PV array industry requires to cut its price without degrading its efficiency so more people can use it [10].The VSI with output *LC* filter is considered as the economical and reliable candidate to provide a sinusoidal voltage to the consumers in the stand-alone systems. Controlling VSI with output *LC* filter is a challenge task in the area of stand-alone systems control. The output voltage regulation of this topology with any kind of load must be highly stable and efficient as it needs to avoid the problems of poor power quality due to high total harmonic distortion (THD)[11]. The load associated with the solar panel must be adjusted to match the current and voltage to supply maximum power. So, it is required to connect a dc-dc converter between the solar panel and load to fulfill the requirements. Boost converter is the best suitable converter as it can increase the dc voltage accordingly. The output voltage (load voltage) from the solar PV feed to boost converter which boost the output and the output can be changed by changing the parameter of boost converter. In this paper single phase inverter is also used. Single phase inverter working on PWM technique is connected to output of boost converter which converts DC to AC.A L-C filter is connected to output of inverter to get a pure sinusoidal wave. The main objective of this paper is the ease with which solar PV energy can be used to run electrical equipment. The proposed system is cheap and works best on standalone.

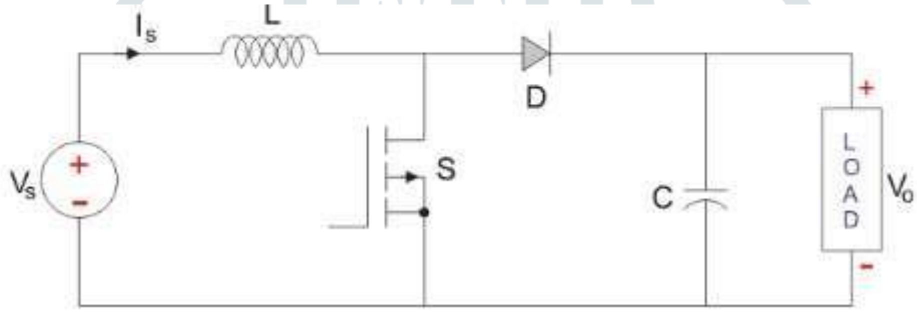
PROPOSED METHODOLOGY:

1. SOLAR PV ARRAY:

A photovoltaic array is a connected linked arrangement of photovoltaic modules. Each photovoltaic (PV) module is made of different interconnected PV cells. The cells convert sun oriented solar power into direct-current electricity. PV modules are in some cases called sun based panels, despite the fact that that term better applies to solar-thermal water or air heating panels. Photovoltaic modules separate themselves from solar cells in that they are advantageously measured and bundled in climate safe lodgings for simple establishment and arrangement in private, business, and modern applications. The application and study of photovoltaic advanced devices is known as photovoltaics. The voltage and current acquired from the PV exhibit relies upon irradiance, temperature, number of arrangement associated strings and number of equal associated strings. In this way, it is required to pick the sort of sunlight based board shrewdly. In this paper, 1Soltech 1STH-215-P panel is chosen over the rundown of given sunlight based modules in MATLAB with 4 equal strings. The determinations of the chosen solar panels are depicted and the readings in the table are given for 10 equal string at an irradiance of 500 W/m2 and 25 degree celsius temperature.

2. DC-DC Boost converter:

DC-DC Boost converter increases the input DC voltage to a specified DC output voltage. The input voltage source is linked to an inductor based system. The igbt(FET resistance=0.1 ohms, internal diode resistance=0.01 ohms) which operates as a switch is connected across the inductor and source. The second forward switch used is a diode. The diode is linked to a capacitor and the load and the two are connected in parallel as shown in the figure below.
The inductor linked to input voltage source results into a constant input current, and thus the Boost converter can be depicted as the constant current input source.
The mathematical equations required for the calculation of parameters of the buck-boost converter are as follows:



Neglecting the voltage drops across the diode and the transistor:

$$V_{out} = \frac{V_s}{(1-D)}$$

DUTY CYCLE:

$$\text{Duty Cycle} = 1 - \frac{V_s}{V_o}$$

VALUE OF CAPACITANE

$$C = \frac{I_o * D}{f_S * \Delta}$$

VALUE OF RESISTANCE

$$\text{Load Resistance} = \frac{V_o}{I_o}$$

VALUE OF INDUCTANCE

$$L = \frac{V_s * D}{f_S * \Delta I_o}$$

The design of the boost converter can be done by calculating the required parameters using the above equations.

3. Single Phase PWM based Inverter

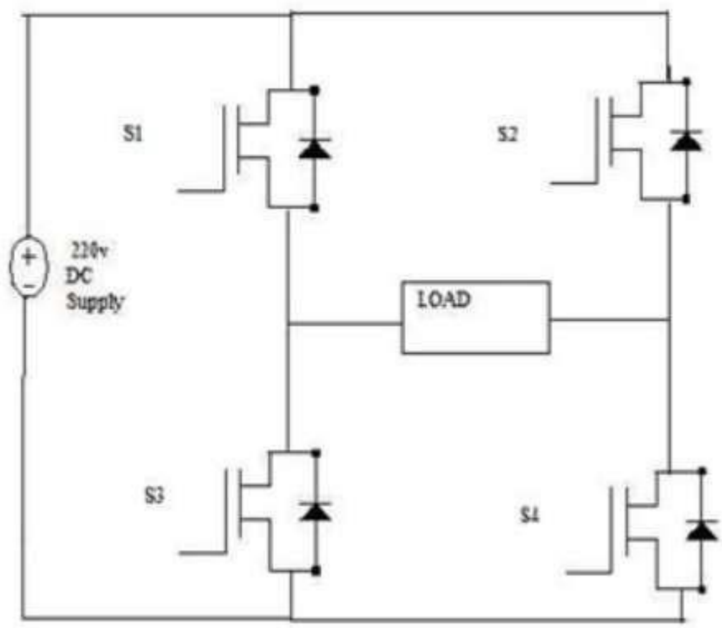
The Pulse Width Modulation (PWM) is a technique which is characterized by the generation of constant amplitude pulse by modulating the pulse duration by modulating the duty cycle. Analog PWM control requires the generation of both reference and carrier signals that are feed into the comparator and based on some logical output, the final output is generated. The reference signal is the desired signal output maybe sinusoidal or square wave, while the carrier signal is either a sawtooth or triangular wave at a frequency significantly greater than the reference.

The DC to AC power converters are known as Inverters. An inverter is a circuit which converts a dc power into an ac power at desired output voltage and frequency. The ac output voltage could be fixed or variable frequency. This conversion can be achieved either by controlled turn on and turn off devices (e.g. BJT's, MOSFETs, IGBTs, MCTs, SITs, GTOs, and SITHs) or by forced commutated thyristors depending on applications. The output voltage waveforms of ideal inverter should be sinusoidal. The voltage waveforms of practical inverters are, however, non-sinusoidal and contain certain harmonics. Square wave or quasi-square wave voltages are acceptable for low and medium power applications, and for high power applications low, distorted, sinusoidal waveforms are required. The output frequency of the inverter is determined by the rate at which the semiconductor devices are switched on and off by the inverter control circuitry and consequently, an adjustable frequency ac output is readily provided. The square wave inverters need switching devices. These switching devices can either be thyristors or transistors and or other power semiconductor devices. Due to their mode of operation, losses in these semiconductor devices are very small and consequently they have a higher efficiency with much more power handling capability. By sequentially switching them on and off, the voltage across the load changes polarity cyclically and produces an alternating voltage / current.

$$V_0 = \sum_{n=1,3,5\ldots}^{\infty} \left(\frac{4Vs}{n\pi} \sin \omega t\right) \text{Volt}$$

$$I_0 = \sum_{n=1,3,5}^{\infty} \left(\frac{4Vs}{n\pi|Zn|} \sin(n\omega t - \varphi)\right)$$

Where Z_n=Load impedance at frequency n.f



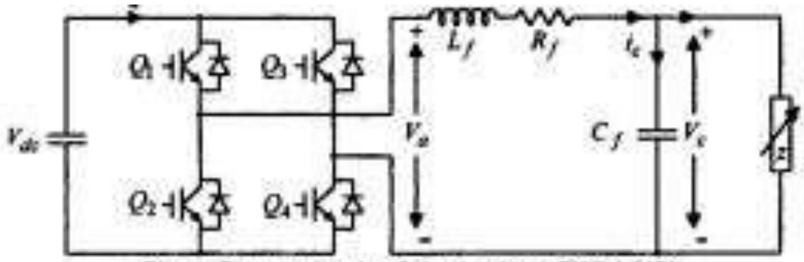


Fig. 1. Power circuit of single phase PWM-VSI.

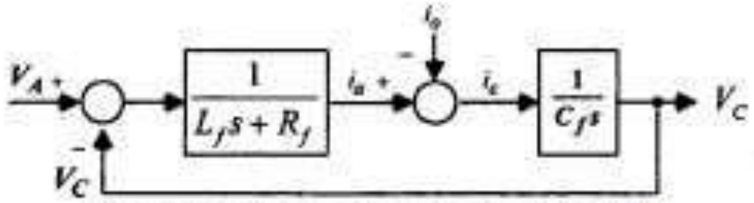


Fig. 2. Block diagram of single phase PWM-VSI.

4. LC Filter

An LC filter combines inductors (L) and capacitors (C) to form low-pass, high-pass, multiplexer, band-pass, or band-reject filtering in radio frequency (RF) and many other applications. Passive electronic LC filters block, or reduce, noise (EMI) from circuits and systems, and separate, or condition, desired signals.

While ideal filters would pass desired signal frequencies with no insertion loss or distortion, and completely block all signals in the stop-band, real filters have DC and AC resistances that contribute to insertion loss, requiring careful component selection. Selecting the exact values of the parts for a particular application requires high quality components as well as complete specifications and performance models. The simplest to design and implement are the low-pass and high-pass types. The LC filter is used to limit the rate of rise of the inverter output voltage and reduce common mode noise to the motor. ... A diode bridge must therefore be used to clamp the resonant voltage. Resistors are also used to help dissipate the energy stored in the resonant circuit. Second-order passive LC-type filters have been widely used on the AC terminals of PWM inverters when the output voltages are the main control targets. The main purpose of the LC filters is to attenuate the voltage ripple that stems from inverter switching. The output voltage on the LC filter capacitor is controlled by switching the PWM inverter, where the LC filters introduce a time delay and cause resonance in the output AC voltage.

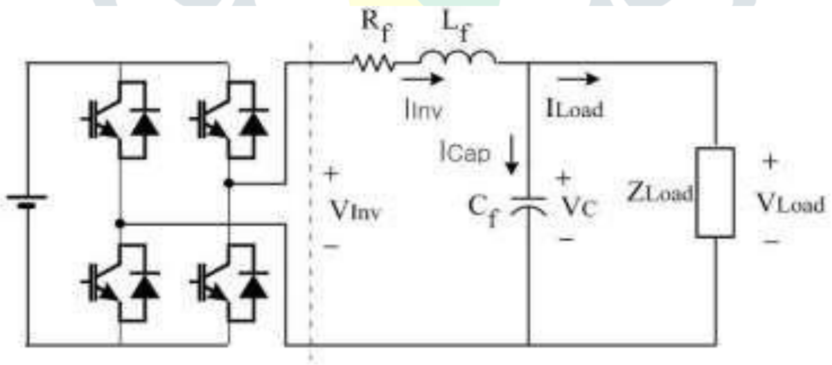
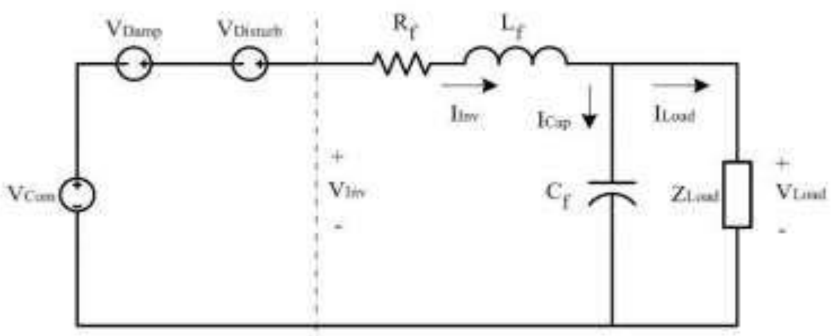


Fig. 1. Single-phase equivalent circuit of a PWM inverter system.

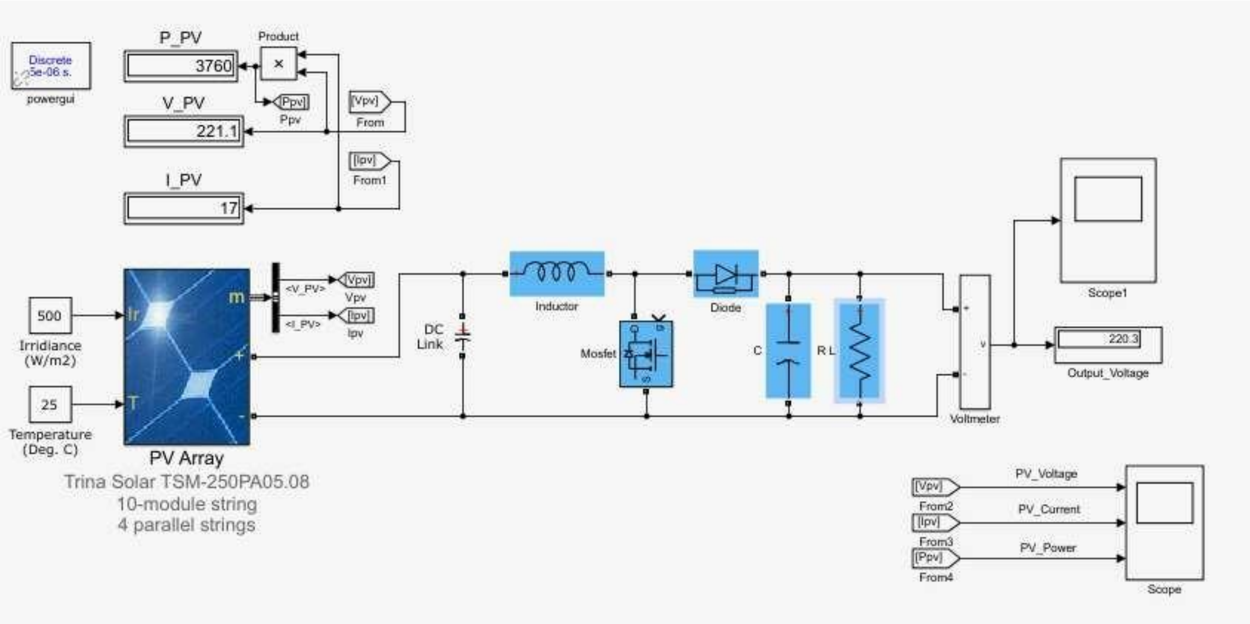


The output regulating voltage VCom regulates the output terminal voltage of a PWM inverter system. When the oscillation damping voltage VDamp and the disturbance -rejection voltage VDisturb are ideally controlled, the load current disturbance becomes completely decoupled and the system-damping factor reaches a state of unity. Hence, the output LC filter serves as a time-delay component with a delay time of 2/ωf in a steady state.

VCom = (1+ (2/ωf)*s)V $_*$ Load where, $\omega_f = 1/\ \mathrm{sqrt}(L_f C_f)$: filter cut-off frequency.

PROPOSED SIMULATION

The following figure is a PV solar array connected to a boost converter which gives 220V DC output. DC-DC conversion takes place here



Figure(a)

The figure(b) is of single phase PWM based inverter with LC to get a pure Sinusoidal wave. DC-AC inversion takes place here

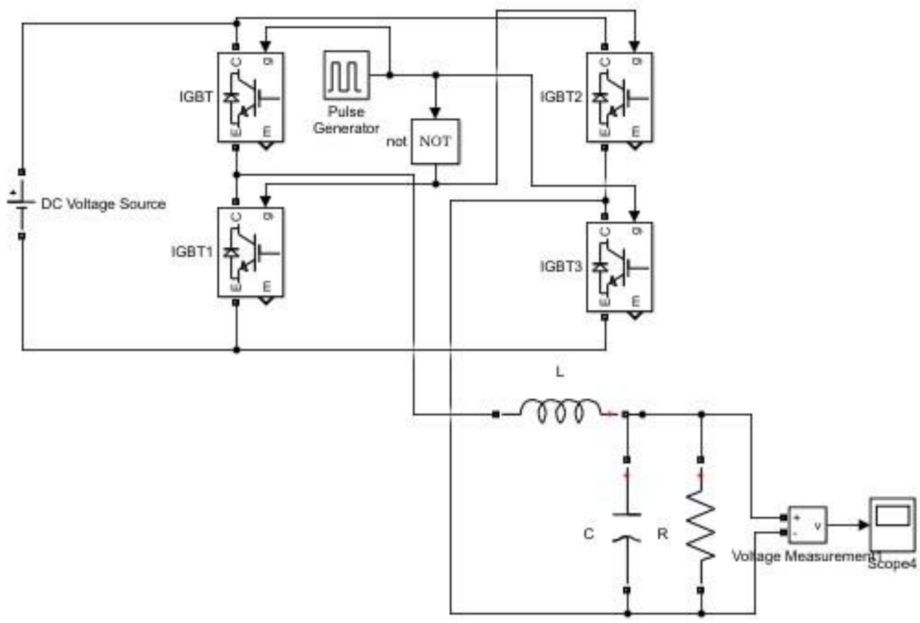
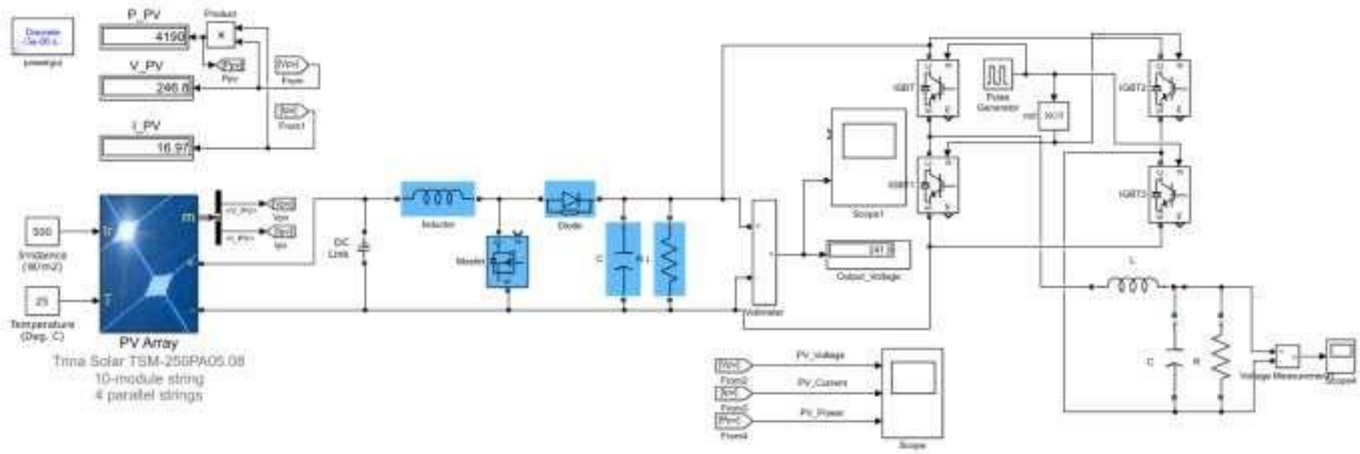


Figure (b)

The proposed system is designed in MATLAB Simulink and the circuit diagram is shown in figure(c)



Figure(c)

The circuit shown in figure(c) is obtain after integrating two circuit since there are two stages of conversion

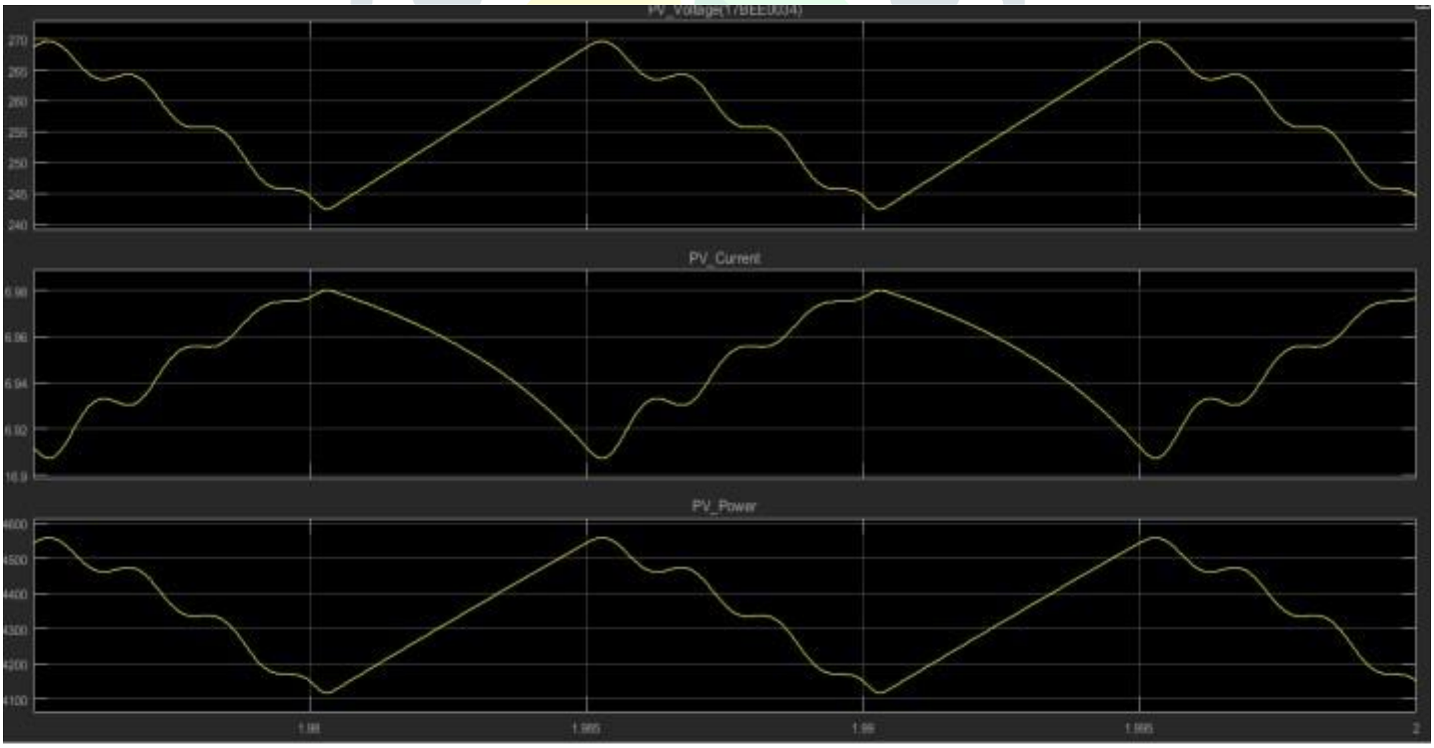
1) DC-DC conversion in Boost Converter

2) DC-AC inversion in single phase PWM inverter

The PV solar array is connected to boost converter and the output from boost converter is fed to single phase PWM based inverter and a LC filter is connected at the output of inverter to get the pure sinusoidal wave.

Results

PV solar cells parameters like voltage, current and power are depicted in graph in following figure(d)

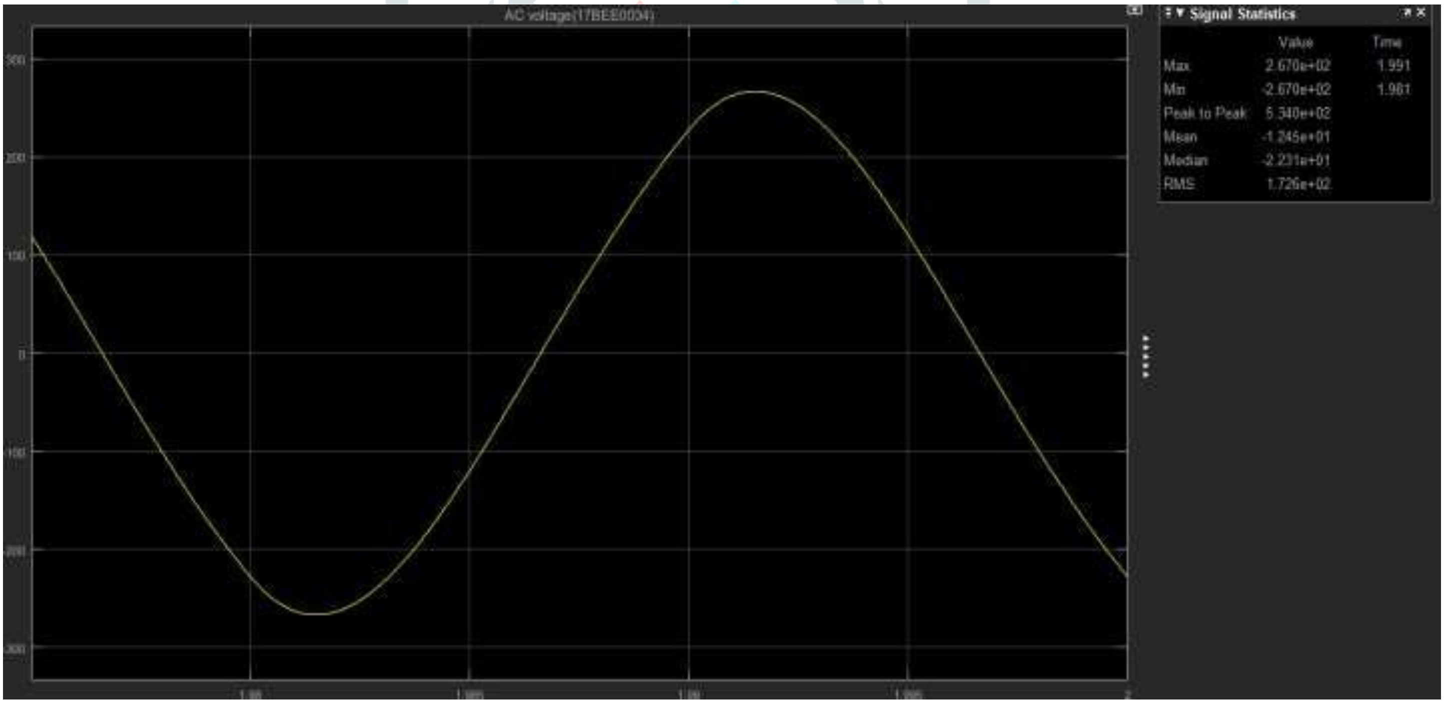


Figure(d)

The output of boost converter (DC-DC conversion) is shown in figure(e)

Graph of Voltage against time
Figure(e)

The output for the boost converter is 220V DC. This DC is fed to single phase PWM based inverter which gives the output (DC-AC inversion) shown in figure(f)



Graph of Voltage against time
figure(f)

Future Reference:

The proposed system can be connected to grid. An irradiation curve can be given to the PV solar array which would most relate to real life applications. MPPT techniques alone with buck-boost converter can be used to get required DC output. A three phase inverter can be connected to get three phase ac supply.

ANALYSIS:

The output of the proposed single phase inverter is purely sinusoidal. Two stage of conversion takes place DC-DC-AC.

In first stage, Boost converter is used to boost the output of PV array to 220V.

In second stage, Single phase PWM based inverter is used to convert Constant DC into Sinusoidal AC with help of LC filter connected across the output of single phase PWM based inverter.

Conclusion:

The proposed system shows how standalone PV array can be used to supply energy to the load. This system is cheap and has greater efficiency. This system is quite simpler and doesn't require bulkier instruments and can be installed anywhere. This system decreases the losses since transmission losses are greatly reduced. Such system can be used in villages where grid connection is sometimes not possible.

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