# Design and Simulation of Renewable Energy Based Photovoltaic Power Plant using MATLAB Simulink

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*Abstract*— Only a small fraction of the available solar energy is used in practice..To harvest the solar energy, the most common way is to use photovoltaic panels which will receive photon energy from sun and convert to electrical energy. The efficiency of PV module is very low and power output depends on solar irradiation level and ambient temperature, so maximization of power output with greater efficiency is of special interest. In this project, Advance DC-DC Converter use for a photovoltaic (PV) power-generation system is proposed. The topology used raises the efficiency for the dc/dc converter of the PV power conditioning system (PVPCS), and it minimizes switching losses by adopting a resonant soft-switching method. The proposed controller scheme utilizes PWM techniques to regulate the output power of dc-d converter at its maximum possible value. This converter is able to turn on both the active power switches at zero voltage to reduce their switching losses and evidently raise the conversion efficiency. Output of DC DC converter is given to in novel H-bridge inverter which maintain sinusoidal output with less harmonic distortion. The resulting system has high-efficiency, lower-cost. The circuit will be simulated using MATLAB.

***Keywords:*** Photovoltaic System, MPPT, DC/DC Converter, DC/AC Converter, Grid Connection, Simulink

## I. INTRODUCTION

Use of renewable energy and in particular solar energy has brought significant attention over the past decades. Photovoltaic (PV) power generation projects are implemented in very large number in many countries. Many research works are carried out to analyses and validate the performance of PV modules. Implementation of experimental set up for PV based power system with DC-DC converter to validate the performance of the system is not always possible due to practical constraints. Software based simulation model helps to analyses the performance of PV and a common circuit based model which could be used for validating any commercial PV module will be more helpful. Simulation of mathematical model for Photovoltaic (PV) module and DC-DC Zeta converter is presented in this project. The model presented in this proposed project can be used as a generalized PV module to analyses the performance of any commercially available PV modules. I-V characteristics and P-V characteristics of PV module under different temperature and irradiation level can be obtained using the model. Simulation of DC-DC Zeta converter is performed and the results are obtained from constant DC supply fed converter and PV fed converter. Also, it can reduce the input current ripple, output voltage ripple, and size of the passive Components. Output of DC DC converter is given to in novel H-bridge inverter which maintain sinusoidal output with less harmonic distortion.

## II. DESIGN OF PV SYSTEM

The design of a PV power generation system, with an installed power of 100Kw
A 100KW PV array is connected to a 25kv grid and DC-DC boost converter , three phase three level voltage source convertor(VSC) maximum power point tracking(MPPT) is implemented in a boost convertor by means of a Simulink model using the incremental conduction +integral regulator technique. The detailed model contains the following component:--

The PV array system consist several photovoltaic cells, which is 66 no. of parallel string and 5 no. of series string and its delivered power 100kw with constant 25◦tempreture and 1000w/m2 irradiance. series connections are responsible for increasing the voltage of module whereas the parallel connection is responsible for increasing the current in the array

DC DC boost convert increased the voltage from the pv voltage 273V DC at maximum power) TO 500v dc switching duty cycle is optimize by the MPPT controller that uses the 'incremental conduction+ integral regulators technique. This MPPT system automatically varies the duty cycle in order to generate the required voltage to extract maximum power.

The VSC converts the 500V DC link voltage to 260V AC and keep unity power factor.

### A. *Design of the PV array*

Consists in cells of series connected monocrystalline cells. The front side of the PV module includes a highly transparent glass sheet, characterized by a significant resistance against mechanic shocks. The frame of anodized aluminium (covered through electrolysis by a layer of protective oxide), forms the structural support of the module. All these provide an adequate protection against atmospheric agents like hail, snow, ice and storm. Each module contains by-pass diodes introduced in the connection (distribution) box. These diodes will allow the "off-lining" of the modules where the sunshine does not reach, in order to prevent their behaviour as consumers for the panels getting radiation from sun and therefore avoiding their undesired heating.

Several models of PV cells are available from manufacturers like Mitsubishi, Sharp, Sanyo, LDK, BP Solar, Suntech.

We selected Sun power SPR-305E-WHT-D PV modules, with a maximum power of 305 W. The technical specifications for one module are given in Table I. The number of necessary series-connected modules per string and parallel strings is determined by the DC-DC boost converter input voltage value and the inverter power.

 

| Parameter | vaValue |
|---|---|
| Parallel string | 66 |
| Series connected module per string | 5 |
| Maximum power (w) | 305.226 |
| Open circuit voltage Voc (v) | 64.2 |
| Short circuit current ISC (A) | 5.96 |
| Voltage at maximum power point Vmp(v) | 54.7 |
| Current at maximum point Imp(A) | 5.58 |

Table 1: Solar Array Parameters

The rated DC input voltage for the boost converter is normally chosen half the output voltage, i.e. the DC-Link voltage.

Considering that the output voltage of a string of series connected PV modules is the sum of the component modules, and also considering the minimum DC-Link voltage for the inverter, one can obtain the number of PV modules connected in series NSER based on:

$$N_{SER} = \frac{1}{2} \times \frac{\text{Vdc}-\text{link}}{\text{Vmp}}$$

where: $N_{SER}$ = number of necessary series connected modules;

$V_{DC\text{-}LINK}$ = the DC-Link voltage at the inverter input;

$V_{MP}$ = PV module voltage at maximum power point;

In this project the temperature of PV Array is varying i.e. 25°c, 40°c, 50°c.

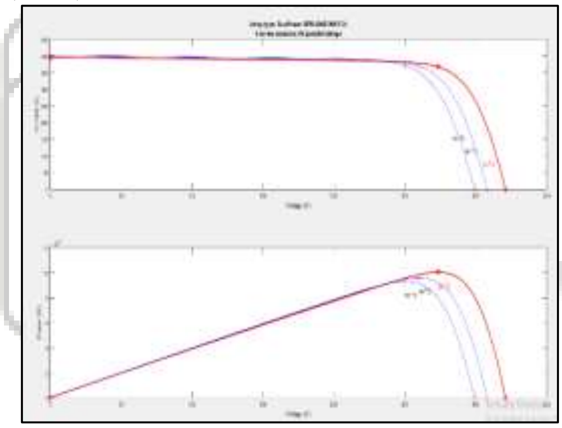

Fig. 4: I-V & P-V Characteristics of Sun power SPR-305E-WHT-D PV Array

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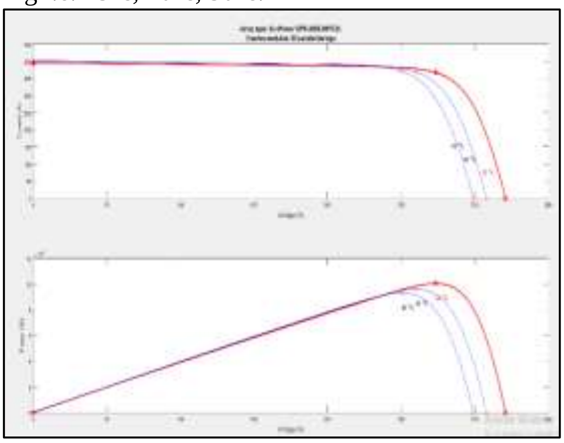


Fig. 2: I-V & P-V Characteristics of Sun power SPR-305E-WHT-D PV Array

*B. DC-DC Boost converter:*

A boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element: a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter).

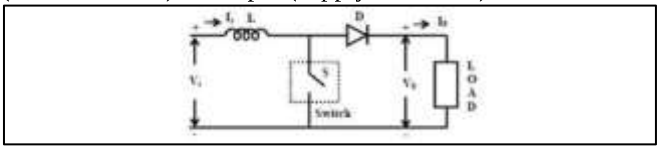


Fig. 3: Construction of Boost Converter

DC-DC converters are used in PV systems to regulate the voltage generated by the PV modules. DC-DC boost converters are used in grid connected applications to step up the module voltage. The circuit diagram of DC-DC boost converter is shown in fig 3.4

The DC-DC boost converter circuit consists of Inductor (L), Diode (D), Capacitor (C), load resistor (RL), the control switch (S). These components are connected in such a way with the input voltage source (Vin) so as to step up the voltage. The output voltage of the boost converter depends on the duty cycle of the control switch. So, the output voltage can be varied by varying the ON time of the switch. Thus, for the duty cycle "D" the average output voltage can be calculated using

$$\frac{\text{Vo}}{\text{Vin}} = \frac{1}{(1-\text{D})}$$

Where, Vin, Vo are the input and output voltage of the converter respectively and D is the duty cycle of the control switch. In an ideal circuit, the output power of the converter is equal to input power which yields.

*1) Selection of Inductor:*

The inductor value of the Boost converter are calculated using

$$\text{L} = \frac{\text{Vin}}{(\text{Fs} \times \Delta\text{Il})} \times \text{D}$$

Where fs, is the switching frequency and ΔIl is the input current ripple. Current ripple factor (CRF) is the ratio between input current ripple and output current. For good estimation of inductor value CRF should bound within 30% i.e.

$$\frac{\Delta\text{Il}}{\text{Io}} = 0.3$$

The current rating of inductor should be always higher than that of the maximum output current.

*2) Selection of Capacitor:*

The capacitor value can be obtained from

$$\text{C} = \frac{\text{Iout}}{(\text{Fs} \times \Delta\,\text{Vo})}\text{D}$$

Where, Δ Vo is the output voltage ripple which is usually considered as 5% of output voltage which yields,

$$\frac{\Delta\text{Vo}}{\text{Vo}} = 5\%$$

*3) Selection of Capacitor:*

The capacitor value can be obtained from

$$\text{C} = \frac{\text{Iout}}{(\text{Fs} \times \Delta\,\text{Vo})}\text{D}$$

Where, $\Delta$Vo is the output voltage ripple which is usually considered as 5% of output voltage which yields,

$$\frac{\Delta Vo}{Vo} = 5\%$$

## III. MAXIMUM POWER POINT TRACKER (MPPT):

### *1) Incremental Conductance:*

Incremental conductance method uses two voltage and current sensors to sense the output voltage and current of the PV array.

At MPP the slope of the PV curve is 0.

$(dP/dV)_{MPP}=d(VI)/dV$ (3.1)

$0=I+VdI/dV_{MPP}$ (3.2)

$dI/dV_{MPP} = - I/V$ (3.3)

The left hand side is the instantaneous conductance of the solar panel. When this instantaneous conductance equals the conductance of the solar then MPP is reached.

Here we are sensing both the voltage and current simultaneously. Hence the error due to change in irradiance is eliminated. However the complexity and the cost of implementation increase.

As we go down the list of algorithms the complexity and the cost of implementation goes on increasing which may be suitable for a highly complicated system. This is the reason that Perturb and Observe and Incremental Conductance method are the most widely used algorithms.

Owing to its simplicity of implementation we have chosen the Perturb & Observe algorithm for our study among the two.

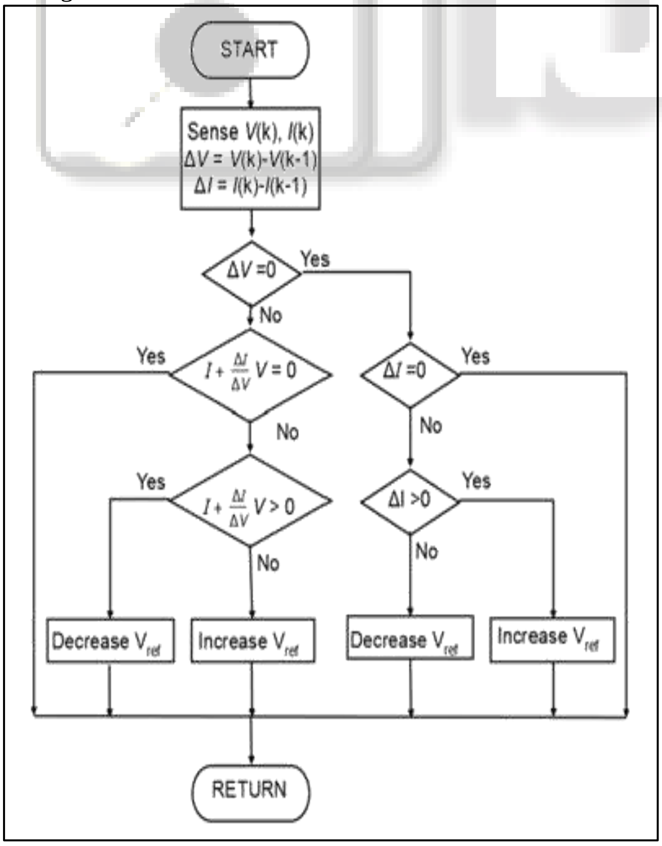



Fig. 5: Flow chart of mppt

## IV. SIMULATION OF PV ARRAY

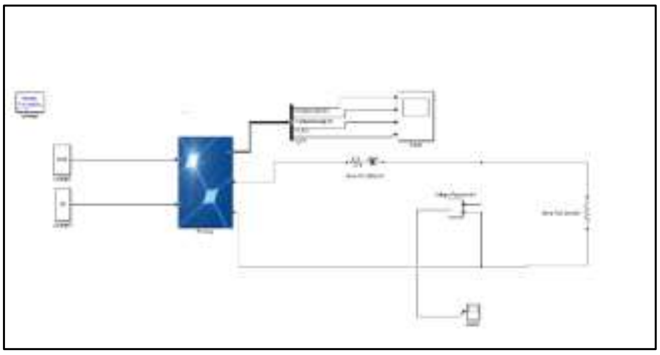


Fig. 6: PV Array without boost converter

Firstly checking the output of the Sun power SPR-305E-WHT-D PV Module without MPPT or DC- DC Boost converter. In this the temperature and irradiation of PV Array is kept constant i.e. 25℃ and 1000 W/$m^2$ respectively.

The 'm' terminal is a Simulink output vector containing five signals. The voltage measurement is connected across the positive and negative terminal of PV Array. The characteristics of above simulation is as follows.

Total voltage of the module can be calculated by

Total voltage = $V_{mp}*N_{series}$

= 54.7*05

=273.5 v

Total current of the module can be calculated by

Total current = $I_{mp}*N_{parallel}$

= 5.58*66

= 368.28 Amp

## V. DESIGNING OF PV ARRAY WITH DC-DC BOOST CONVERTER AND SIMULINK:

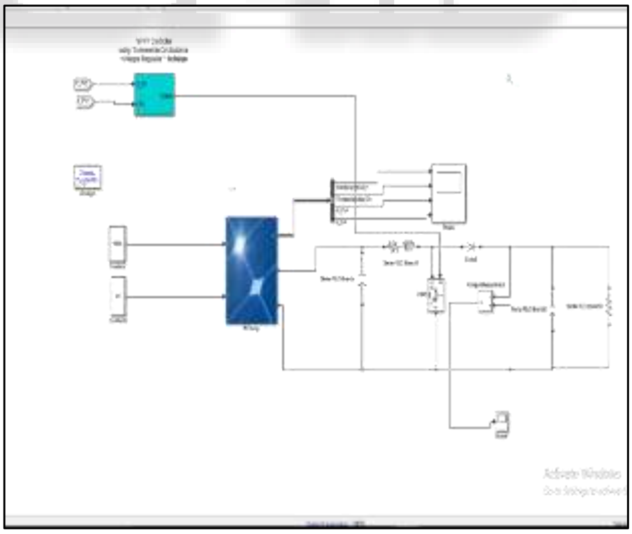
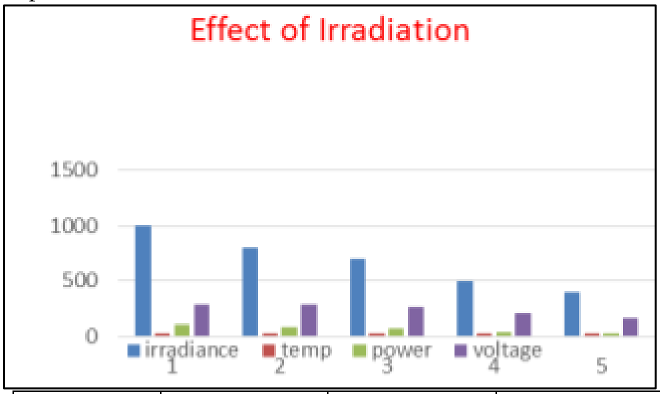


Fig. 7: circuit diagram of PV Array with boost converter

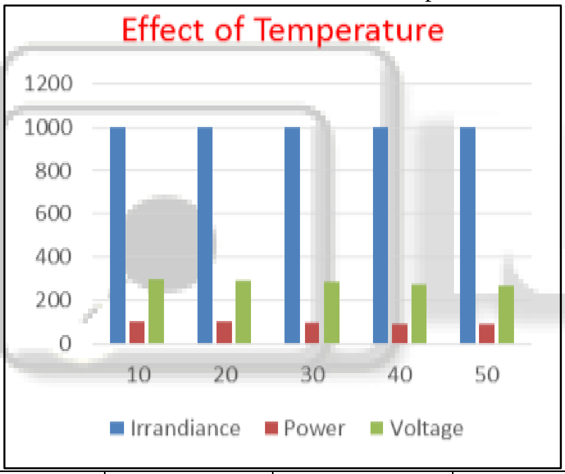
Secondly checking the output of the Sun power SPR-305E-WHT-D PV Module with MPPT or DC- DC Boost converter. In this the temperature and irradiation of PV Array is kept constant i.e. 25℃ and 1000 W/$m^2$ respectively.

The 'm' terminal is a Simulink output vector containing five signals shown in above figure. In the source side we are using a boost convertor connected to a solar panel in order to enhance the output voltage so that it can be used for different applications like motor load. By changing the duty cycle of the boost converter appropriately we can match the source impedance with that of the load impedance.




| irradiance | temp | power | voltage |
|---|---|---|---|
| 1000 | 25 | 99.6 | 288 |
| 800 | 25 | 80 | 282 |
| 700 | 25 | 69.4 | 260 |
| 500 | 25 | 37.5 | 200 |
| 400 | 25 | 24.3 | 156.2 |

Table 2: Effect of Irridiation on power




| Temp | Irrandiance | Power | Voltage |
|---|---|---|---|
| 10 | 1000 | 100.5 | 300 |
| 20 | 1000 | 100 | 293 |
| 30 | 1000 | 98 | 285 |
| 40 | 1000 | 90 | 275 |
| 10 | 1000 | 100.5 | 300 |

Table 3: Effect of Irridiation on power

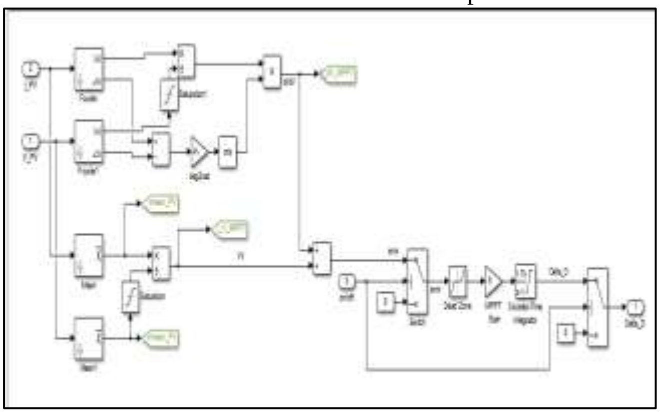


Fig. 8: subsystem of MPPT

Incremental conductance method uses in the MPPT, two voltage and current sensors to sense the output voltage and current of the PV array.

At MPP the slope of the PV curve is 0.

$(dP/dV)_{MPP}=d(VI)/dV$

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$dI/dV_{MPP} = - I/V$

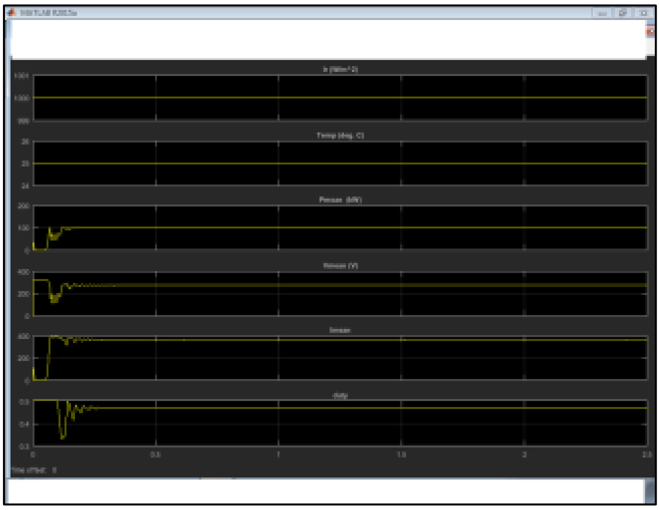

Fig. 10: Waveform of PV Array with boost converter

## VI. DESIGNING PV POWER PLANT AND SIMULINK:

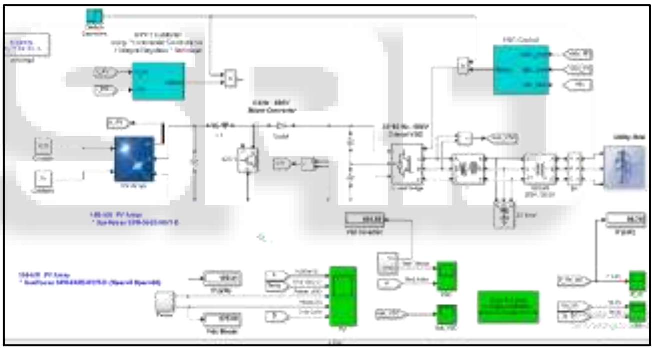

Fig. 9: circuit diagram of proposed project

A 100-kW PV array is connected to a 25-kV grid via a DC-DC boost converter and a three-phase three-level Voltage Source Converter (VSC). Maximum Power Point Tracking (MPPT) is implemented in the boost converter by means of a Simulink model using the 'Perturb & Observe' technique.

Another example (see power_PVarray_grid_det model) uses detailed models for the DC_DC and VSC converters. In this detailed model the MPPT controller is based on the 'Incremental Conductance + Integral Regulator' technique. The average model contains the following components.

– PV array delivering a maximum of 100 kW at 1000 W/m^2 sun irradiance.
– DC-DC boost converter (orange blocks)
– 3-level 3-phase VSC (blue blocks).
– 100-kVA 260V/25kV three-phase coupling transformer.

In this average model the boost and VSC converters are represented by equivalent voltage sources generating the AC voltage averaged over one cycle of the switching frequency. Such a model does not represent harmonics, but the dynamics resulting from control system and power system interaction is preserved. This model allows using much larger time steps than the detailed model (50 microseconds vs 1 microsecond), resulting in a much faster simulation. Note that in the average model the PV-array model contains an algebraic loop. This algebraic loop is required to get an iterative and accurate solution of the PV model when large sample times are used. This algebraic loop is easily solved by Simulink.

The 'Perturb and Observe' MPPT algorithm is implemented in the MPPT Control Matlab Function block. The 100-kW PV array consists of 66 strings of 5 series-connected 305.2-W modules connected in parallel (66*5*305.2 W= 100.7 kW). Manufacturer specifications for one module are:

- Number of series-connected cells : 96
- Open-circuit voltage: Voc= 64.2 V
- Short-circuit current: Isc = 5.96 A
- Voltage and current at maximum power : Vmp =54.7 V, Imp= 5.58 A

The PV array block has two inputs that allow you varying sun irradiance (input 1 in W/m^2) and temperature (input 2 in deg. C). The irradiance and temperature profiles are defined by a Signal Builder block which is connected to the PV array inputs.

Run the model and observe the following sequence of events on Scopes.

Simulation starts with standard test conditions (25 deg. C, 1000 W/m^2).

From t=0 sec to t= 0.3 sec, duty cycle of boost converter is fixed (D= 0.5 as shown on PV scope). Resulting PV voltage is therefore V= (1-D)*Vdc= (1-0.5)*500=250 V (see V_PV trace on PV scope). The PV array output power is 96 kW (see Pmean trace) whereas specified maximum power with a 1000 W/m^2 irradiance is 100.7 kW. Observe on Grid scope that phase A voltage and current at 25 kV bus are in phase (unity power factor).

At t=0.3 sec MPPT is enabled. The MPPT regulator starts regulating PV voltage by varying duty cycle in order to extract maximum power. Maximum power (100.7 kW) is obtained when duty cycle is D=0.453.

From t=0.3 sec to t=0.5 sec, the PV array operates at standard test conditions (25 deg. C, 1000 W/m^2). Duty cycle D varies between 0.450 and 0.459. PV voltage = 273.5 V (Nser*Vmp=5*54.7= 273.5 V) and mean power = 100.7 kW as expected from PV module specifications.

From t=0.5 sec to t=1.0 sec, sun irradiance is ramped down from 1000 W/m^2 to 250 W/m^2. It can be seen that this type of MPPT controller tracks maximum power only while irradiance stays constant.

From t=1.0 sec to t=1.5 sec when irradiance stays constant and equal to 250 W/m^2, duty cycle D varies between 0.466 and 0.474. Corresponding PV voltage and power are V_PV= 265 V and Pmean=24.4 kW.

From t=1.5 sec to t=6.0 sec sun irradiance is restored back to 1000 W/m^2 and then temperature is varied between 50 deg. C. and 0 deg. C. in order to observe impact of temperature. Note that maximum PV output power (107.5 kW) is obtained at minimum temperature (0 deg.

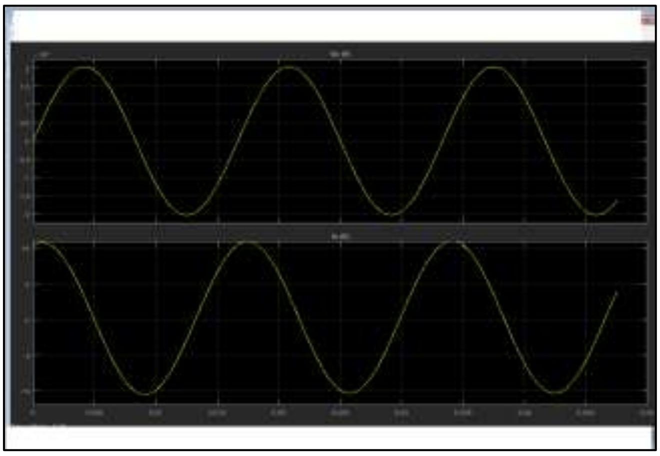

Fig. 11: Waveform of grid connected

## VII. OBSERVATION TABLE:

*1) When change in temperature the effect on output power:*

| IRRADIATION | TEMPERATURE | POWER (kW) | VOLTAGE (V) | VOLTAGE OF CONVEERTER (V) | GRID POWER (kW) |
|---|---|---|---|---|---|
| 1000W/m² | 25° | 100.31 | 275.5 | 499.89 | 98.78 |
| 800 W/m² | 25° | 80.16 | 273.85 | 499.81 | 78.5 |
| 600 W/m² | 25° | 59.79 | 274.35 | 499.9 | 58.8 |

*2) When change in irradiation the effect on output power:*

| IRRADIATION | TEMPERATURE | POWER (kW) | VOLTAGE (V) | VOLTAGE OF CONVEERTER | GRID POWER (kW) |
|---|---|---|---|---|---|
| 1000W/m² | 25° | 100.31 | 275.5 | 499.89 | 98.78 |
| 1000W/m² | 40° | 95.7 | 263.37 | 500.3 | 94.06 |
| 1000W/m² | 50° | 92.9 | 251.98 | 500.3 | 91.7 |

## VIII. CONCLUSION:

In this study, Matlab Simulink model or Matlab model of a PV module has been developed. The proposed model takes sunlight irradiance and cell temperature as input parameters. I-V and P-V output characteristics under various conditions are obtained. Sun power PV module parameters have been used for modelling. Furthermore, model can be easily applied with other PV module parameters. Also the output voltage of the PV module is increased by DC/DC boost converter and also reduces the total harmonics distortion. In this proposed module successfully 100 kW power is generated and fed to the grid and improving the efficiency of the grid system.

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