Single Phase Grid-Connected Photovoltaic System with Maximum Power Point Tracking

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ABSTRACT

Renewable energy in recent year has become more and more common, due to the pollution and depletion in the level of fossil fuels. In this project we are going to use solar energy and the application of that energy with the reliable and efficient way. This system consists of a switch mode DC-DC boost converter and an H-bridge inverter. The switching strategy of proposed inverter consists with a combination of sinusoidal pulse width modulation (SPWM) and square wave along with grid synchronization condition. In PV module, system is implemented using Maximum Power Point Tracking method utilized to increase system efficiency. Normally the total power i.e. active power is supplied from PV system and reactive power is taken from the grid. We will utilize active power from renewable energy source and reactive power from grid and supply to load. The initial cost will be more but it will be one time investment. The entire system will be simulated in MATLAB/SIMULINK environment.

Keyword : - *Renewable Energy Source, Solar Cell, MPPT, DC-DC Boost Converter, Grid Tie Inverter (GTI), Linear Load*

1. INTRODUCTION

The growing interest in environmental issues and the energy market have led to a growing share of grid connected power system in the public power network. Alternative sources of electric power are fuel cell (FC), Wind energy, solar energy, Biomass energy etc. Solar (photovoltaic) energy is a major renewable energy source at the front of stand-alone and distributed power systems. Photovoltaic (PV) power systems are dependent on climatic conditions and their output depends on the time of year, time of day and the amount of clouds. The main idea of the control strategy is to utilize the PV energy to the maximum by using maximum power point tracker (MPPT) and the rest of the power that cannot be met by the PV should be supplied by the grid.

2. SIMULATION AND OUTPUTS

2.1 Solar Cell Modelling

Solar cells made of a p-n junction fabricated in thin layer of semiconductors, whose electrical characteristics differ very little from a diode represented by the equation of Shockley. Thus the simplest equivalent circuit of a solar cell is a current source in parallel with a diode as shown in Fig -1. So the process of modelling this solar cell can be developed based on equation. [3]

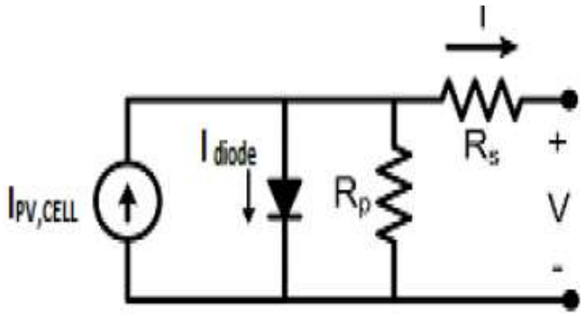


Fig -1 Equivalent model of Solar cell

$$I = I_{PV,CELL} - I_{Diode} \qquad (1)$$

$$I = I_{PV,CELL} - I_{O,CELL}\left[exp\left(\frac{q*V}{\alpha*k*T}\right) - 1\right] \qquad (2)$$

Where;

$I_{PV,\ CELL}$ = Current generated by the incident light
I_{DIODE} = Shockley diode
$I_{0,\ DIODE}$ = Reverse Saturation or leakage current
q = Electron Charge (1.6021*10-19)
k = Boltzmann constant (1.3805*10-23)
T = Temperature of the PN junction diode
α = Ideality constant (between 1 to 2)

In practical model of PV array several components are connected in series or parallel so in solar cell requires the additional components are Rs and Rp.

$$I = I_{PV} - I_0\left[\exp\left(\frac{V+Rs*I}{Vt*\alpha}\right) - 1\right] - \frac{V+Rs*I}{Rp} \qquad (3)$$

The light generated current of the model depend on irradiation G and also temperature.

$$I_{PV} = \left(I_{PV,n} + K_1\Delta T\right)\frac{G}{G_n} \qquad (4)$$

Where;

K_1 is the temperature coefficient of short circuit current
G is the irradiance (W/m^2)
G_n is the irradiance at standard operating conditions.
The diode saturation current Io dependence on temperature can be expressed as

$$I_0 = I_{o,n}\left(\frac{T_n}{T}\right)^3 EXP\left[\frac{q*E_g}{\alpha*k}\left(\frac{1}{T_n} - \frac{1}{T}\right)\right] \qquad (5)$$

Where;

E_g is the band gap energy of the semiconductor
$I_{o,n}$ is the saturation current

$$I_{o,n} = \frac{I_{SC,n}}{\left[EXP\left(\frac{V_{OC,n}}{V_{t,n}*\alpha}\right) - 1\right]} \qquad (6)$$

So , $\boldsymbol{I_o} = \frac{I_{SC,n}+K_1\Delta T}{\left[EXP\left(\frac{V_{OC,n}}{V_{t,n}*\propto}\right)-1\right]}$ (7)

Where;

V_{oc} is open circuit voltage
$I_{SC,n}$ is the short circuit current
$V_{t,n}$ is the thermal voltage
T_n is the temperature at standard operating condition

2.2 Simulation of PV Cell

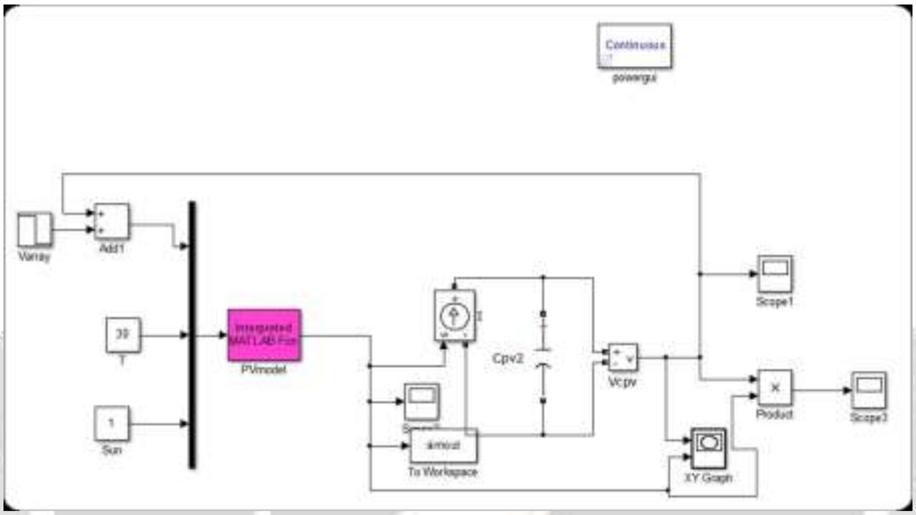
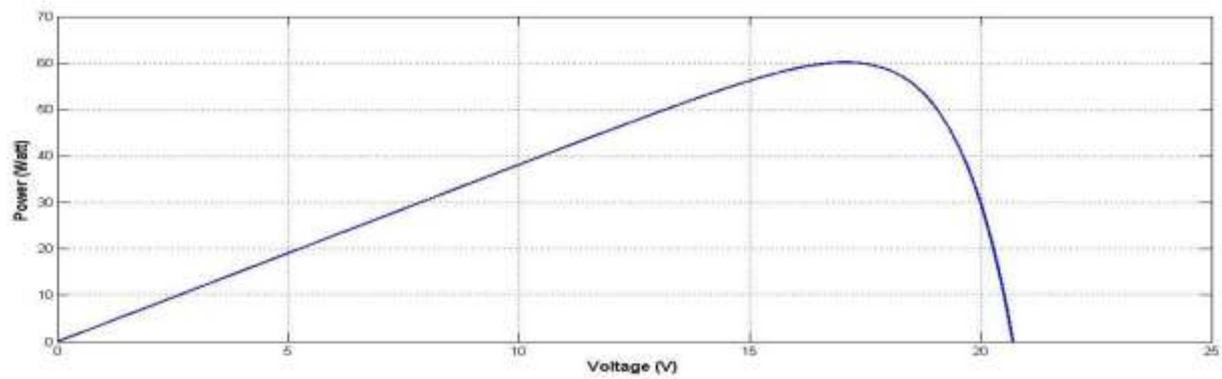


Fig -2 Simulation model of PV Cell

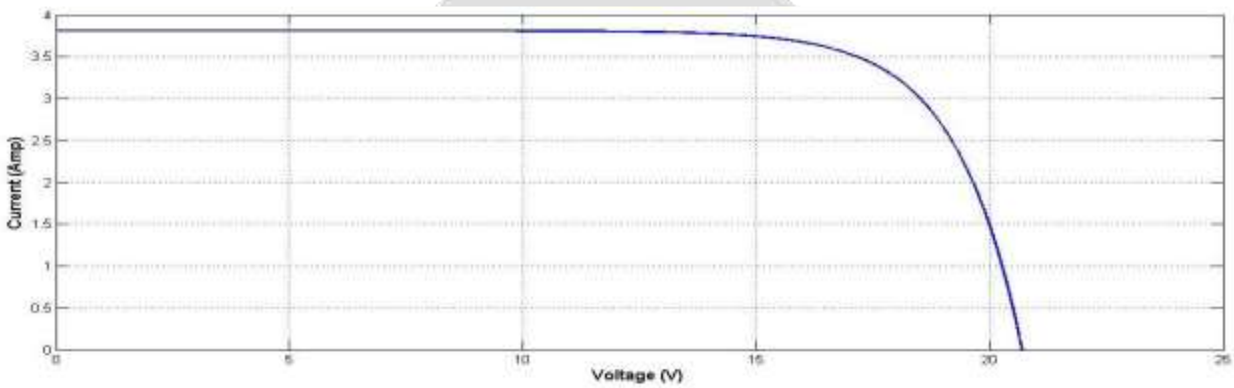
In the above simulation model mainly three inputs are given it is voltage, sun which is irradiation and temperature which is shown in simulation model. We module PV model which is made by implementing the theory equation and in this all the remain parameters, remain constant and evaluating equations and find the output current of one PV cell. In this model one sun is equal to 1000 irradiance and for initial temperature or reference temperature is 25 ^{0}C. [6] Output of the PV cell is tabulated in Table -1. The P-V Characteristic and I-V Characteristic of PV Array is shown in Fig-3.

Table -1 Output data of PV cell

	PV Cell	Unit
At Temperature (T)	25.0	^{0}C
Open Circuit Voltage (Voc)	21.0	V
Short Circuit Current (Isc)	3.74	A
Maximum power (Pm)	60	W



P-V characteristic of PV Cell



I-V characteristic of PV Cell

Fig -3 Simulation Output of PV Cell

2.3 Simulation of PV Array

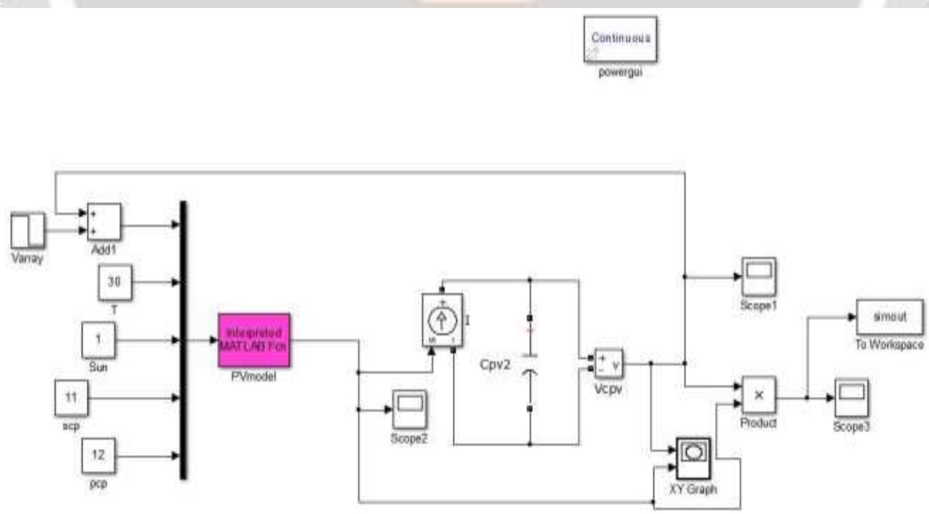
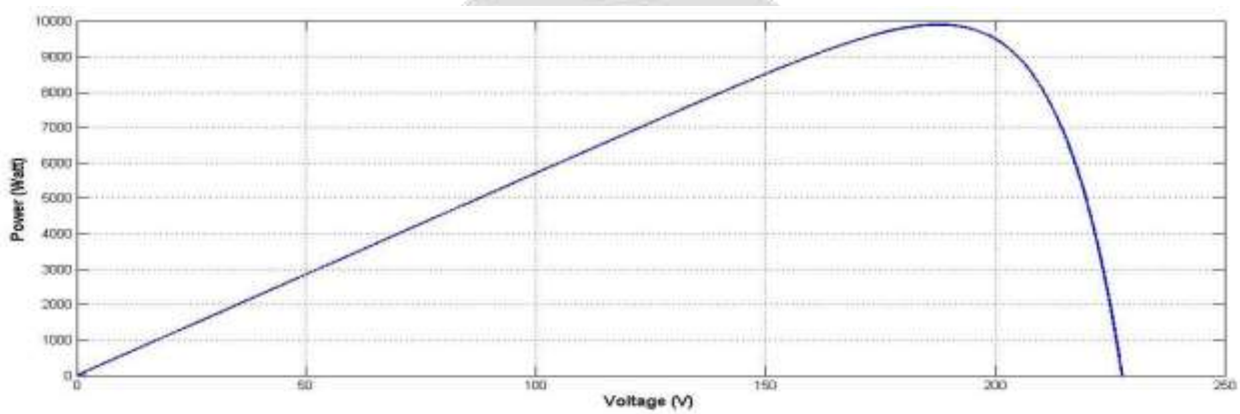


Fig -4 Simulation model of PV Array

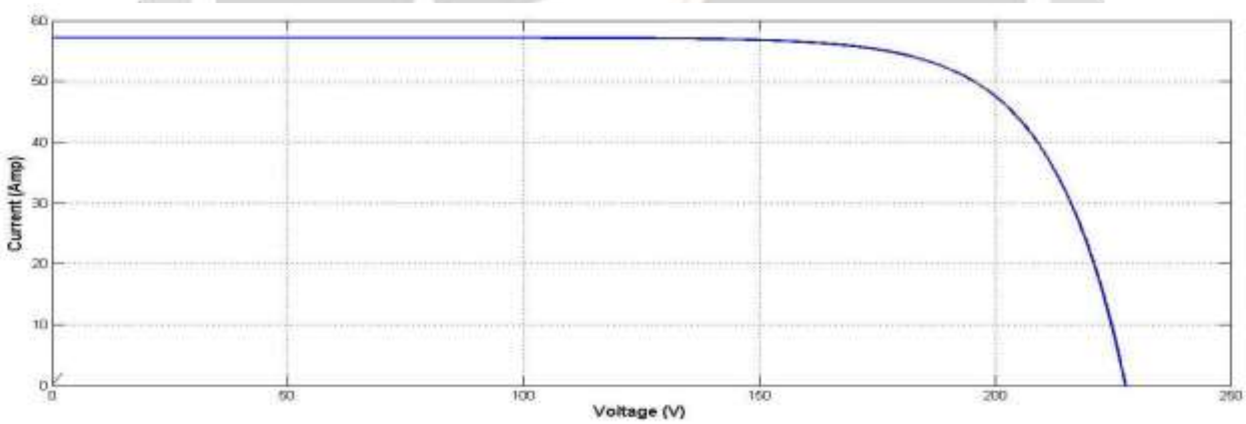
We connect the 11 PV cell in series or 12 PV cell in parallel and make a PV array. Due to this type of connection we get higher output power. It can be done according to if we connect series connect the solar cell then the output voltage will increases and solar cell connect in parallel then output current increases. After connection of series and parallel PV cell we get desire output of PV Array which is tabulated in Table-2. The P-V Characteristic and I-V Characteristic of PV Array is shown in Fig-5.

Table -2 Output data of PV Array

	PV Array	Unit
At Temperature (T)	25.0	^{0}C
Open Circuit Voltage (Voc)	230	V
Short Circuit Current (Isc)	59.4	A
Maximum power (Pm)	10,000	W



P-V characteristic of PV Array



I-V characteristic of PV Array

Fig -5 Simulation Output of PV Cell

2.4 Simulation of Maximum Power Point Tracking (MPPT)

A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. Maximum power point tracking technique is used to improve the efficiency of the solar panel. 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. To implement MPPT we use Perturb and Observe algorithm which output is duty cycle. [6] By changing the duty cycle of the boost converter appropriately we can get maximum output.

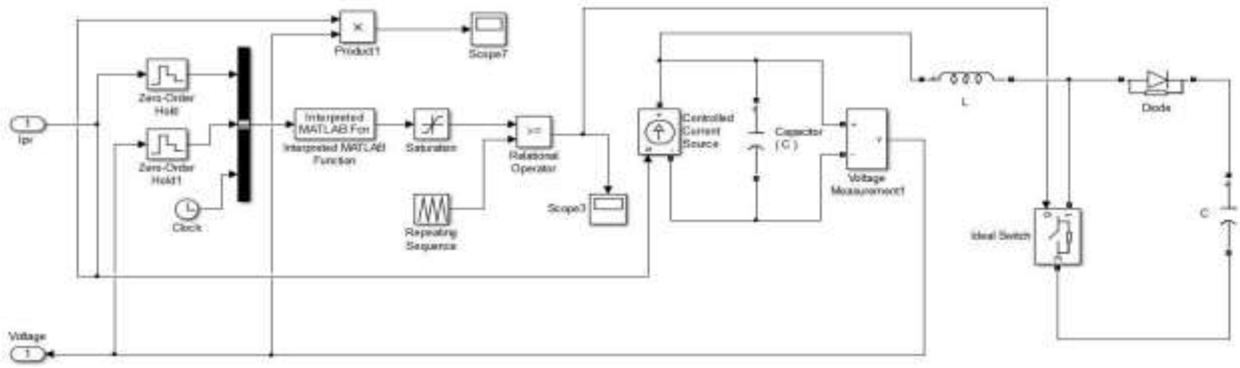


Fig -6 Simulation of MPPT with Boost converter

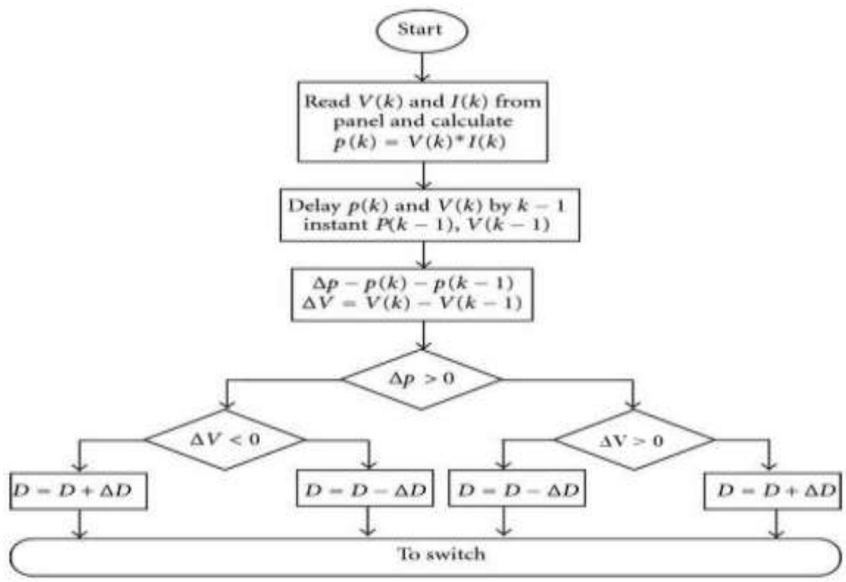


Fig -7 Perturb and Observe algorithm

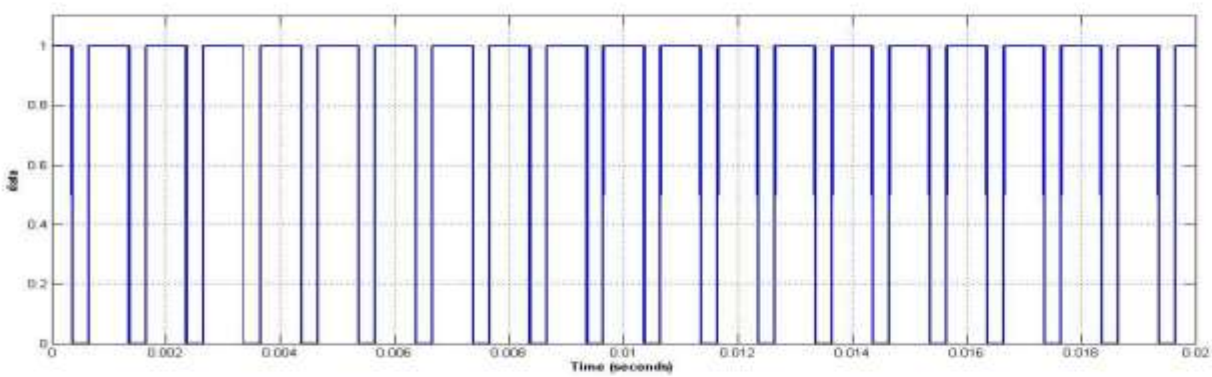


Fig -8 Output of MPPT duty cycle

2.5 DC-DC Boost Converter

To boost the available dc voltage to require level by using a boost converter. The DC input to a boost converter can be from many sources as well as batteries, such as rectified AC from the mains supply, or DC from solar panels, fuel cells, dynamos and DC generators. The boost converter is different to the Buck Converter in that its output voltage is equal to, or greater than its input voltage. However it is important to remember that, as power (P) = Voltage (V) * Current (I), if the output voltage is increased, the available output current must decrease. [5]

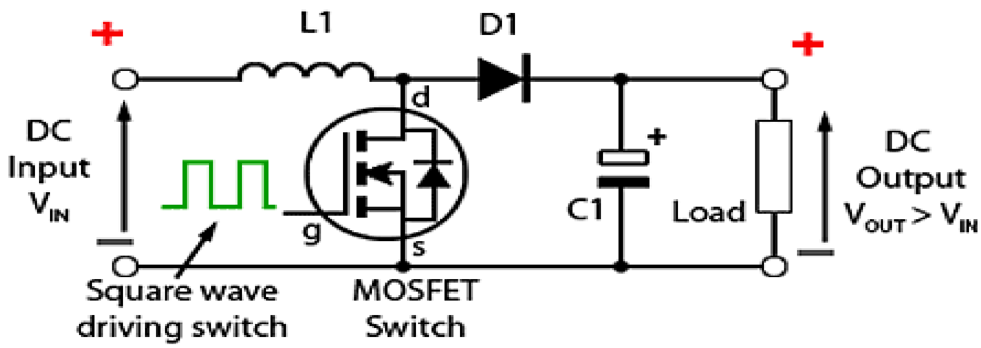


Fig -9 Basic circuit of boost converter

2.6 Control circuit of inverter

In conventional inverters only one type of switching technique is used. This proposed design instead uses a combination of SPWM and square wave to reduce the switching loss by reducing the switching frequency. That shows the proposed switching circuit of the grid-tie inverter (GTI).

For the simplicity an analog oscillator or digital to analog converter (DAC) is omitted, instead the sine wave is sampled from power grid by using transformer that steps down voltage from 220V to 5V. The sine wave sampled is used to generate the SPWM signal thus ensuring output voltage from GTI will have same frequency as the grid. [4]

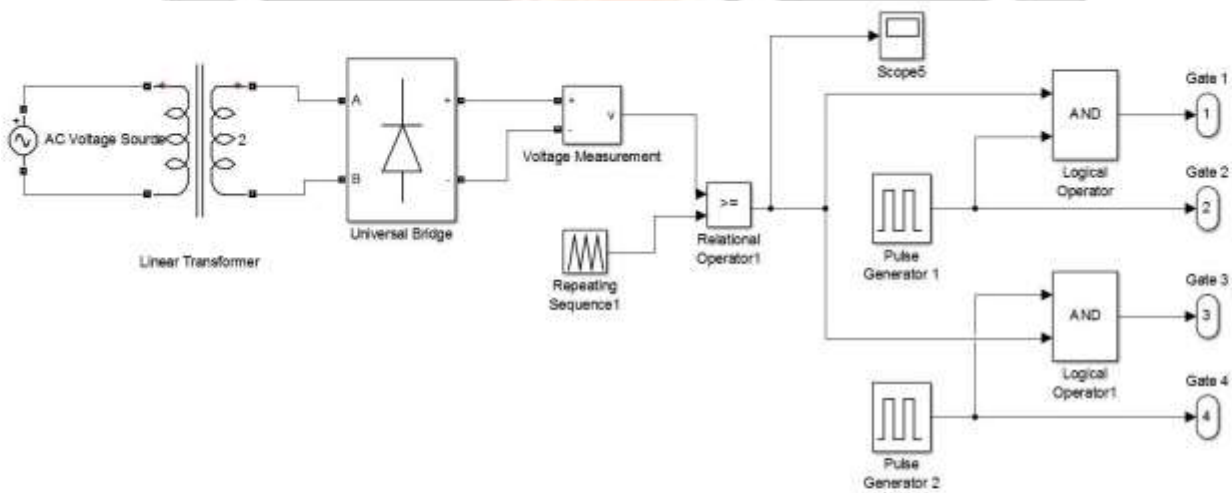


Fig -10 Control circuit of inverter

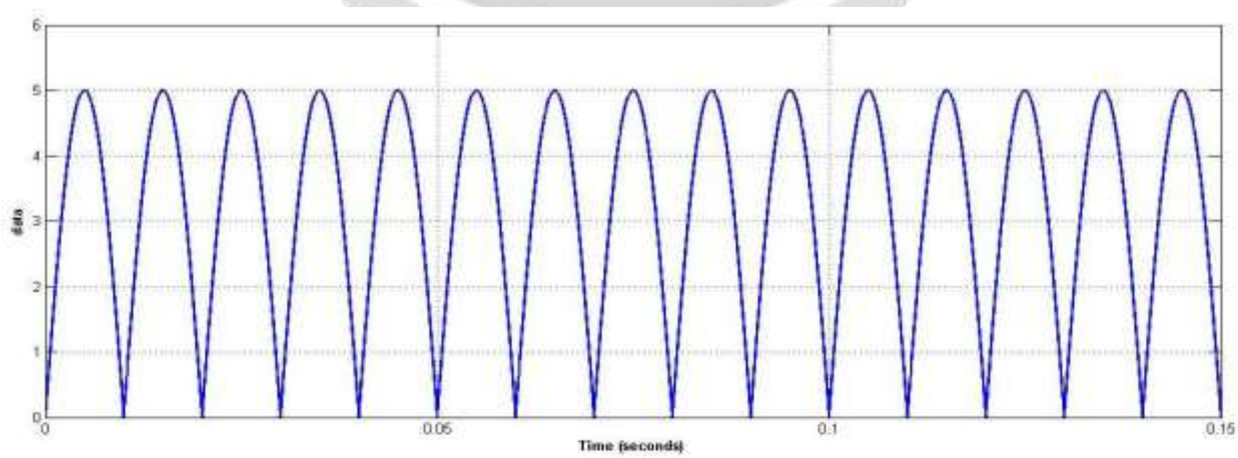


Fig -11 Rectified sine wave

After simulation of control circuit of inverter we get four gate pulses to control the inverter switching operation. Gate pulses are G1, G2, G3, G4 and that's output waveform will show in Fig -12.

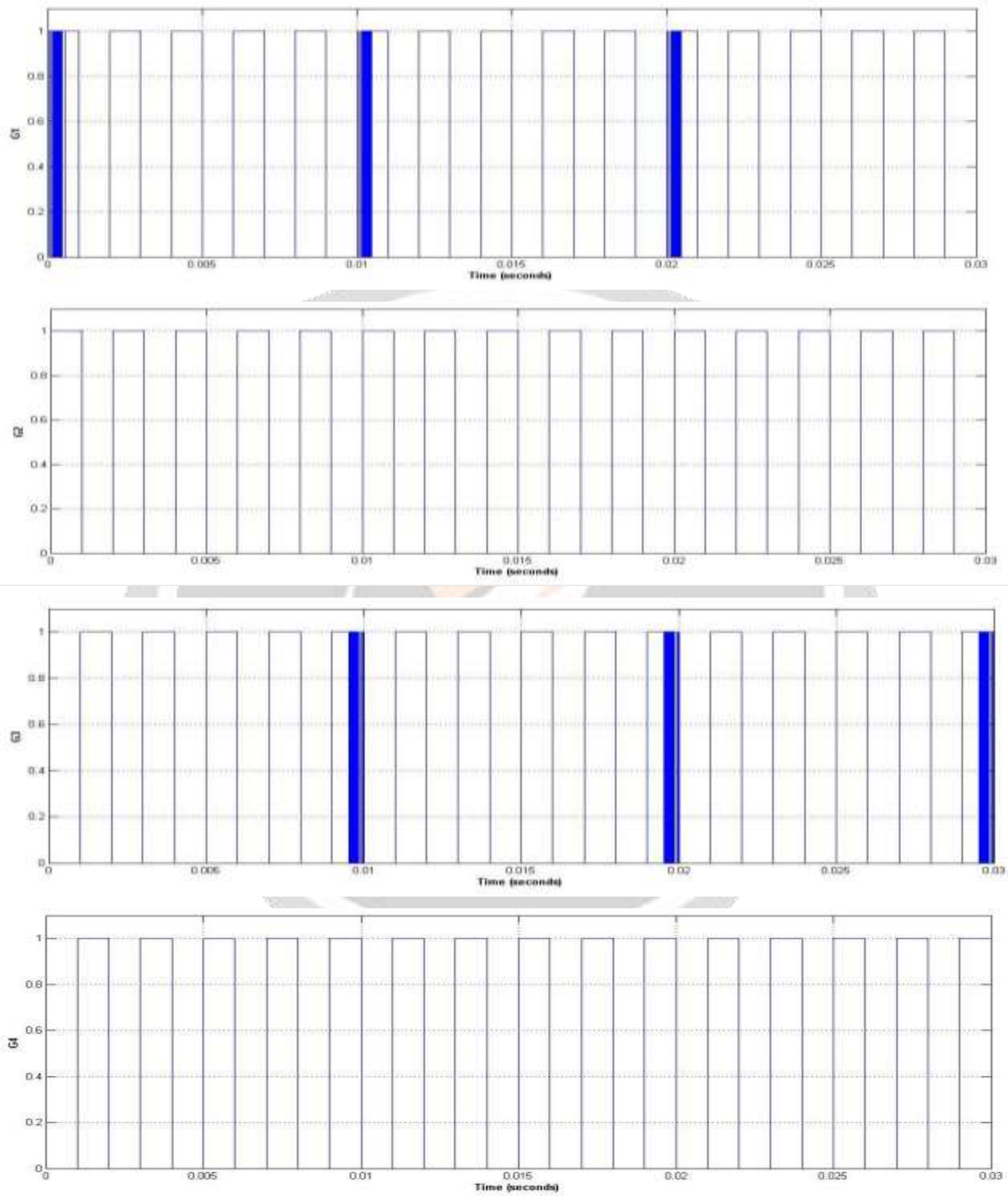


Fig -12 Gate pulses G1, G2, G3, and G4

2.7 Inverter with L-C filter

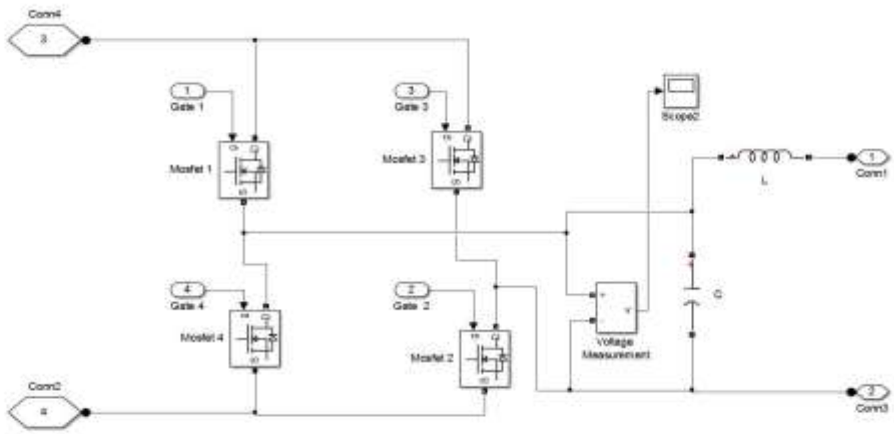


Fig -13 Simulation circuit of inverter with L-C filter

The inverter requires four switching signals since it has four MOSFET switches. To create four signals an AND operation is performed between two sets of square wave signals and the SPWM. The four sets of switching signals can be categorized in two groups. The first group contains MOSFETs Q1 & Q2 while the second group contains MOSFETs Q3 & Q4.

Inverter operation can be divided into two parts:

- Synchronizing
- Power transmitting

During synchronization, the inverter will produce the output in phase with the grid. This is performed by sampling the sine wave and setting phase shift to zero. This un-shifted sine wave is rectified and compared with high frequency triangle wave to generate SPWM signal. An AND operation is performed between the SPWM and the square wave signal to produce four sets of switching signal. With this type of switching and zero phase shifts occurring the inverter output voltage will be controlled by the same phase as the grid.

With inverter and grid voltage in phase the zero crossing of both voltages is detected. Once zero crossing is found contact between grid and inverter is activated and connects the grid and inverter together. After both voltages are connected the inverter begins to transmit power into the grid. A low pass L-C filter is employed in order to eliminate harmonic influence in output waveform. That means harmonics are eliminated with the changes of the value of inductor and capacitor that are connected as L-C filter. [4]

2.7 Grid connected operation

In this voltage and current are simultaneous operated for the generation of power we supplied to grid that requires this kind of need. Output of voltage to supplied to load or grid that show in Fig -14 and current to supplied will be shown in Fig -15.

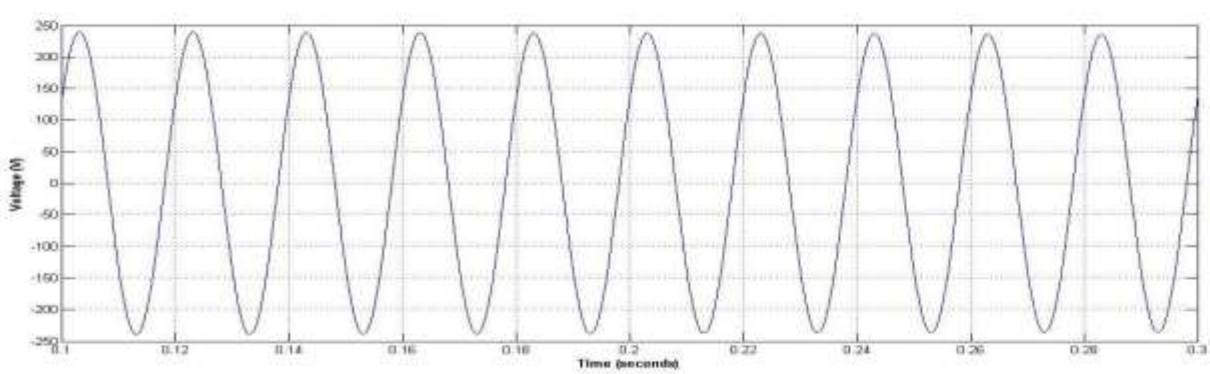


Fig -14 Output voltage that supplied to grid

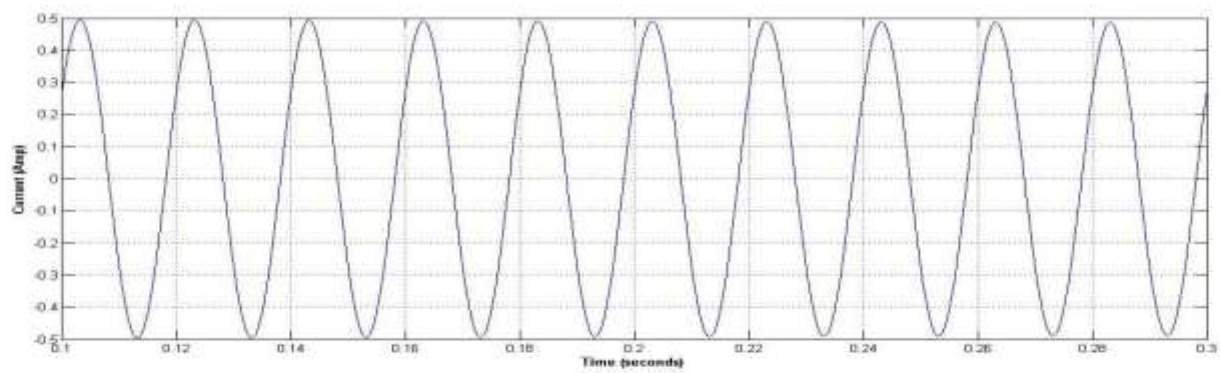


Fig -15 Output current that supplied to grid

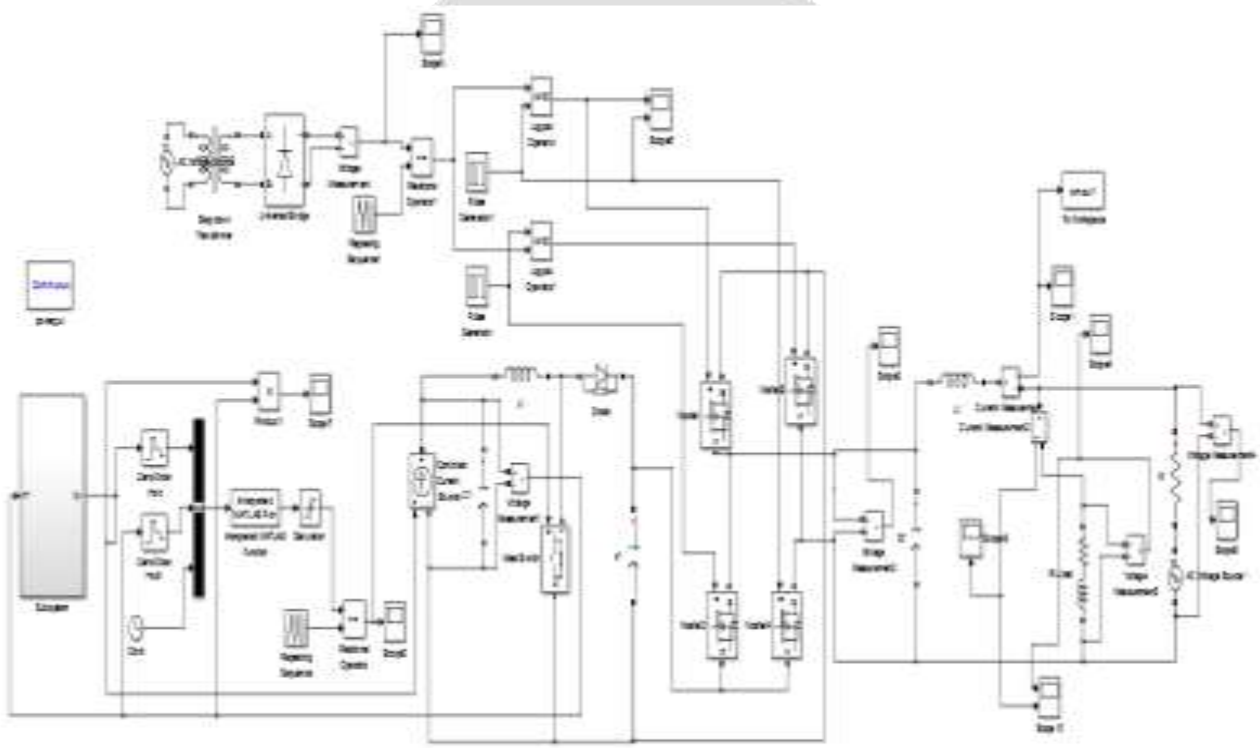


Fig -16 Full system simulation diagram

3. CONCLUSION

The main purpose of this project is to establish a model for the grid-connected photovoltaic system with maximum power point tracking function for residential application. A single phase two-stage grid-connected photovoltaic inverter with a combination of SPWM and square-wave switching strategy is designed using MATLAB. In this system solar cell and solar array implemented with the MATLAB program. In the MPPT algorithm using a boost converter is designed to operate using (P&O) method to control the PWM signals of the boost converter, which is adapted to the maximum power tracking in our PV system. The simulation results show that the proposed grid connected photovoltaic inverter trace the maximum point of solar cell array power and then converts it to a high quality ripple free sinusoidal ac power. The simulation also confirms the proposed photovoltaic inverter to supplies the AC power to utility grid line.

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