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Tracking Maximum Power Point of a PV Array based on Change in Conductance Method

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Abstract: ***In this paper we are going to see how the MPPT algorithm is used to obtain maximum power using a booster converter from a PV array. The booster converter steps up the voltage to required level. The main aim is to track the maximum power point of a solar module and there by using it effectively and efficiently.***
Keywords: Irradiation, MPPT, converter, inverter, Pulse width modulation.

I. INTRODUCTION

Now a days due to increase in the power utility and the decrease in the availability of non-renewable resources is a major problem. So, we are using renewable resources to meet the demand together with non-renewable resources. The renewable sources which we are using at the present time are wind energy and solar energy which are the major resources for the electrical energy in renewable sources. Due to usage of fossil fuels for the hundreds of years since industrialization, fossil fuels are at the point of ending this also cause the change in environment which degrading the biosphere and increasing the global warming. Solar energy is the renewable source which is highly available in nature which made it possible to harvest and utilize it properly. Solar energy itself can be used for generation or can be used with grid connected generating you need depending on the availability of a grade nearby.so it can be used to supply power to rural areas where the grid availability is very low. Another advantage of solar energy is portable operation whenever wherever needed. In order to reach present energy needs we have to develop efficient process to extract power from the incoming solar radiation. In the last decades the power conversion mechanism has been reduced in size. The improvement in power electronics and material science has helped engineers to build very small but powerful systems to withstand present huge power demand. The increased power density is the disadvantage of this system. Trend has been set to use the multi-input converter units that can effectively handle the voltage fluctuations. But due to the production cost is costlier and the efficiency is low for the system they cannot withstand in the competitive market as a primary power generation source. due to constant increase in development of solar cells Technology would definitely make the use of these technologies in future. The latest power control mechanism which we use is called as maximum power point tracking (MPPT) algorithms
which led to the increase in the efficiency of operations of the solar panels and thus is effective in the field of utilization of renewable sources of energy.

A. Objective

The basic objective is to study MPPT and successfully implement the MPPT algorithm either by using in code form or in MATLAB. Modelling the converter and the solar cell in MATLAB and interfacing both with the MPPT algorithm to obtain maximum power point tracking operation is the primary objective.

B. Solar cell Modelling

1) Modelling of a Solar Cell

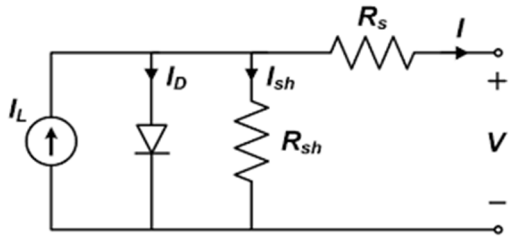


Fig. 1 Single diode model of a solar cell

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A solar panel is the combination of the solar cells. A PV module is formed by connecting solar cells in series and parallel combination. Consider a single solar cell; it can be designed by the current source used, a diode and two resistors. This model is also called as single diode model of the solar cell. Two diode models are also available but here we are using single diode model.

I = Ilg – Ios * [exp{q * – 1} - (1)

Where,

Ios = Ior * * [exp{q * Ego * } (2)

Ilg = {Iscr + Ki ∗ (T − 25)} ∗ lambda (3)

I & V : Cell output current and voltage;

Ios : Cell reverse saturation current;

T : Cell temperature in Celsius;

k : Boltzmann's constant, 1.38 * 10-23 J/K;

q : Electron charge, 1.6*10-19 C;

Ki : Short circuit current temperature coefficient at Iscr;

lambda : Solar irradiation in W/m^2;

Iscr : Short circuit current at 25 degree Celsius;

Ilg : Light-generated current; Ego : Band gap for silicon;

A : Ideality factor; Tr : Reference temperature;

Ior : Cell saturation current at Tr; Rsh : Shunt resistance; Rs : Series resistance;

The characteristic equation of a solar panel is dependent on the number of cells in parallel and series. From experimental results it is studies that the variation of current is not much dependent on the shunt resistance rather it is more dependent on the series resistance.

I = Np*Ilg – Np * (4)

The I-V and P-V curves for a solar cell are given in the following figure. It can be seen that the cell operates as a constant current source at low values of operating voltages and a constant voltage source at low values of operating current.

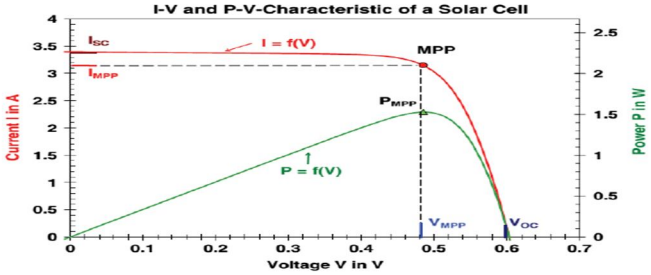


Fig. 2 P-V I-V curve of a solar cell

C. Effect of Variation of Solar Irradiation

The P-V and I-V curves of a solar cell are dependent on solar irradiation values. The solar irradiation keeps fluctuating due to change in environment in a day, but control mechanism is available which tracks these changes and can alert the working of the solar cell to meet the load demand. Higher the solar irradiation, higher would be the solar input to the solar cell and hence the power magnitude would increase for the same voltage level. The open circuit voltage increases with the increase in solar irradiation. Disease caused due to, when more sunlight incidents on the solar cell, the electrons receive more energy and gets in higher excitation state having higher excitation energy, which increases the electron mobility which in turn generates more power.

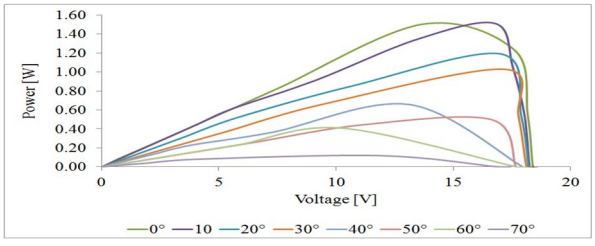


Fig. 3 Variation of P-V curve with solar irradiation

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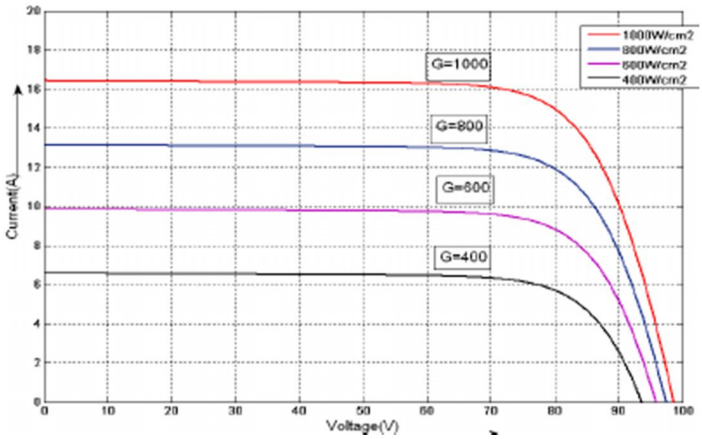


Fig. 4 Variation of I-V curve with solar irradiation

D. Effect of Variation of Temperature

On the other side the power generation capability decreases with the increase in temperature around the solar cell. The open circuit voltage value decreases with the increase in temperature. This causes increase in band gap of the material so that more energy is required to cross the barrier.so the efficiency of solar cell is reduced.

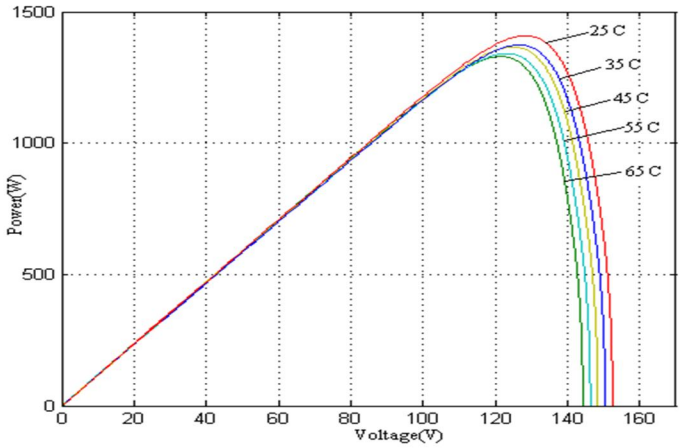


Fig. 5 Variation of P-V curve with temperature

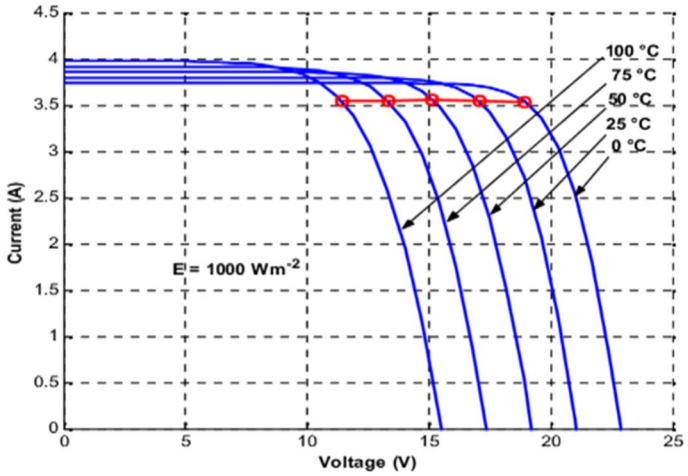


Fig. 6 Variation of I-V with temperature

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II. BOOST CONVERTER

It is a class B chopper. It does the stepping up of output voltage in required manner. It has an inductor, a diode and a switch. The output voltage depends on the duty cycle of the switch. Duty cycle is defined as the ratio of ON time period to the total time period.

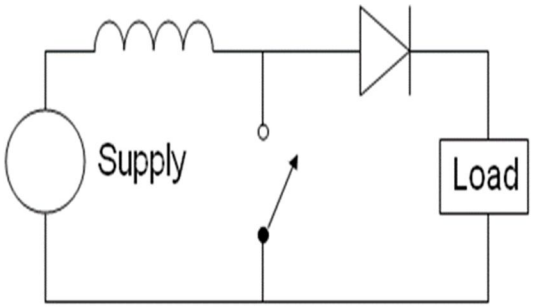


Fig. 7 Boost converter

A. Working

In the working process we can observe the boost converter is operated in two modes. The modes are charging mode and discharging mode.

B. Charging Mode

In this mode of the capacitor shown in the chopper acts as voltage source. Now after closing the switch, we can observe the charging of inductor while charging, diode is reverse biased.

C. Discharging Mode

In charging mode, the diode won't allow current to pass through it and in discharging mode, the diode is forward biased, the amount of voltage that is being charged will now discharge because the switch is being opened.

III. MPPT

We know that the solar panel (or) a PV panel's efficiency is around 15 to 20%. In order to increase its efficiency and to make sure that the solar cell is being used efficiently and effectively we need to extract maximum power from it. A method to extract maximum power is MPPT, using MPPT algorithm we can vary the duty cycle of boost converter. MPPT has different algorithms, each one ultimately run towards extracting maximum power in different ways. Among them we use incremental conductance method.

A. Incremental Conductance Method

We are going to observe the maximum power point by making $\frac{dP}{dV}$= 0. In this method the algorithm follows certain steps and to achieve maximum power equation as stated above. This detects rapid change in irradiation, problem in this method is it requires large number of sensors.

$$\frac{dP}{dV} = \frac{d(V*I)}{dV} \quad (1)$$

$$\frac{dP}{dV} = I * \left\{\frac{d(V*I)}{dV}\right\} + V * \left\{\frac{dI}{dV}\right\} \quad (2)$$

$$\frac{dP}{dV} = \mathrm{I} + V * \left\{\frac{dI}{dV}\right\} \quad (3)$$

When the maximum power point is reached the slope $\frac{dP}{dV}$ = 0. Then the condition would be

$$\frac{dP}{dV} = 0 \quad (4)$$

$$\mathrm{I} + V * \left\{\frac{dI}{dV}\right\} = 0 \quad (5)$$

$$\frac{dI}{dV} = -\frac{I}{V} \quad (6)$$

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B. Flowcharts

In flowcharts algorithm will be explained in a sequential manner. Flowchart is a diagrammatical representation of an algorithm, the way of direction in obtaining output will depend upon the conditions. The inputs taken here are voltage and current at consecutive time intervals. Now difference between the two values of voltages and currents will be taken. If there is a difference in voltage the value of $\frac{dI}{dV} = -\frac{I}{V}$ will be checked and depending on that value the reference voltage will change. If there is no change in two values of voltages that means ΔV=0, then it will check ΔI=0 condition and depending on the above relation the reference voltage will change. Every block in the flow chart is being designed to make sure that maximum power is obtained.

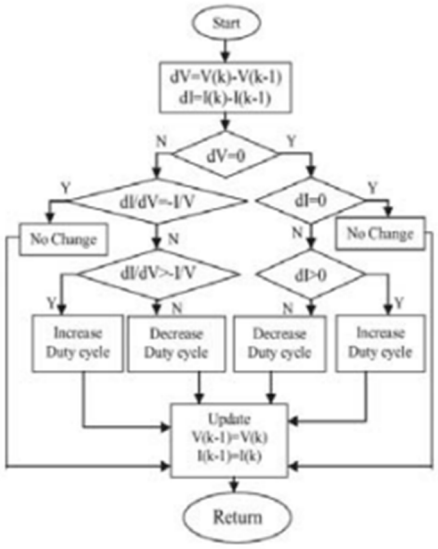


Fig. 8 Flow chart of change in conductance method

IV. SIMULATION LINK MODEL

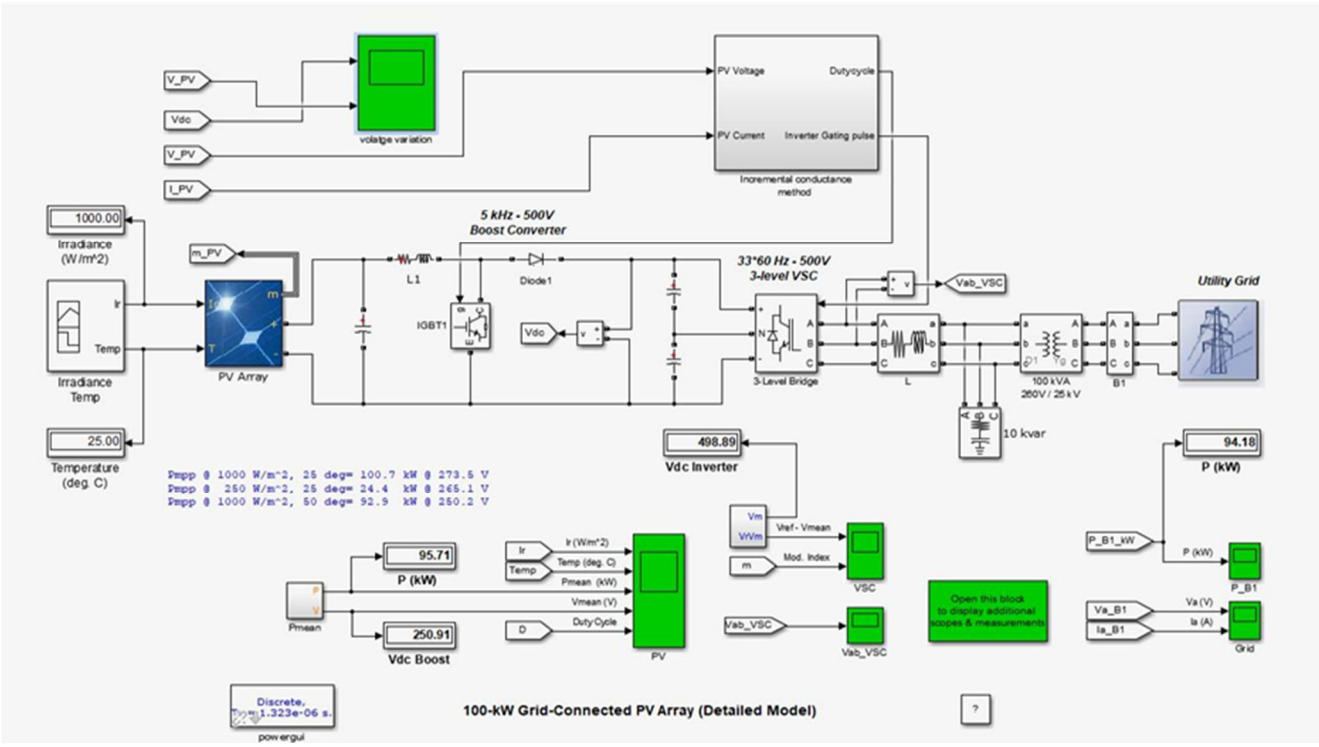


Fig. 9 Simulation model

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In this model we are going to see the layout of the MPPT simulation link model. Solar cell is represented as a PV array having modules connected in series and in parallel links. The input here is irradiance and that is being taken along with the temperature. The output voltage of PV array is given to a dc chopper. The chopper acts as a DC transformer, it steps up the voltage to required level. Depending on the MPPT algorithm the duty cycle of the chopper will vary accordingly. Calculated and measured values can be seen in the scopes. Now we need to convert DC voltage into AC voltage. We use an inverter, in which we use pulse width modulation technique. The output of inverter has harmonics which needs to be filtered. we use filters and in them using fourier analysis we take the fundamental components which are free from harmonics. That output will be stepped up using a transformer and will be given to grid.

A. Photovoltaic Cell

A photovoltaic cell or a solar cell converts light energy directly into electrical energy. The energy converted from one form to another form by the photovoltaic effect. The photovoltaic cell is an electrical device in which photovoltaic effect is due to physical and chemical changes in the panel, it is the phenomena in which voltage and current are produced due to exposure of light, so that electrons in the Solar Panel gets energized or excited. The MPPT is designed with the help of equivalent circuit of the solar cell, the equivalent circuit consists of series resistance and a shut resistance with a current source.

The simulation model of solar cell consists of various blocks that include temperature and irradiance blocks connected to the controlled current source, the diode represented in the block connected parallel to the current controlled source having shunt resistance Rsh parallel to it, series resistance Rs is connected in series to the circuit, the current in the series is represented by I pv and the voltage across the cell is represented by V pv block.

The output current is given to the I *filter* Block and output voltage is given to the V *filter* block so that the unwanted disturbances can be filtered out, the output of the filtered voltage is given by V d=Vpv+Rs*Ipv (1)

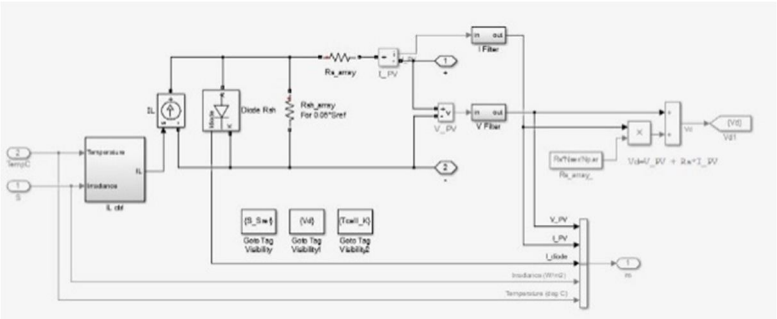


Fig.10 Solar cell modelled in single diode format

B. I LG Generator Unit

This block is used for representing the current generation due to light from sun. It is based on the characteristic equations. The output of the Ilg generator unit is given as input to the signal diode. The voltage Vabc prim and the Iabc prim are given to PLL and Measurement blocks. It consists of various blocks they are PLL, measurement block, current regulator block, Vdc regulator block, Uabc reference generation block, unit delay block & PWM generator (3 level). The output of the Ilg generator unit gives pulses based on the light incident on photovoltaic cell.

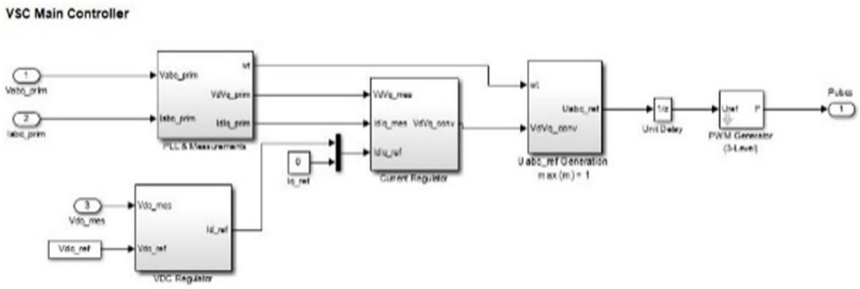


Fig.11 Ilg generator unit

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C. MPPT with Gating Signal

This unit can be explained with the help of two units separately, they are

1) MPPT unit and

2) The gating signal generator unit

The MPPT unit continuously check out the various combinations of voltages and currents and tries to find out the maximum power point simultaneously due to variations in temperature and irradiance. signal generator gives signals to MPPT to increase the inputs accordingly to obtain the maximum power point.

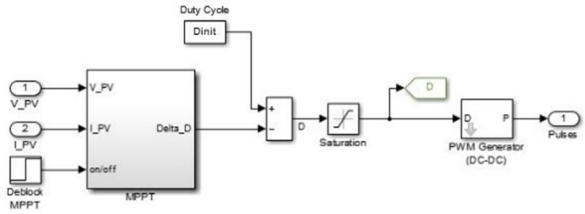


Fig.12 MPPT with gating signal unit

V. INVERTER

The basic operation of the inverter is to convert energy in the form of DC to energy in the form of a AC. There is a need of conversion of energy from DC to AC. Output of solar cell is DC, it is used for Small applications and in order to use for larger applications we need to convert from DC to AC it is possibly by inverter.

There are two types of inverters based on supply power

1) single phase inverter and 2) Three phase inverter Again three phase inverter are classified on based on the conduction mode1)180 mode 0f conduction and 2)120 mode of conduction.

The output of the inverters basically looks like sine wave with the continuous fluctuations here the output of the inverter in MPPT technique can be explained with the help of unipolar pulse width modulation. The unipolar pulse width modulation is the sampling of sinusoidal wave which is useful for the analysis of single and three phase inverters. Carrier waves helps for the production of output for 3 phase 3 level inverters, optimized waves of voltages and currents are obtained by PWM.

A. Introduction to Filter

Filters are interconnected elements of resistors inductors and capacitors. Filters are the devices used to eliminate the unwanted signal from the output of the inverter. We use three phase harmonic filter, in which RLC elements are interconnected. They filter the signals from various unwanted elements like harmonics and give out with the purified output which does not contain any impurities. Harmonic filters are capacitive in nature so that they are helpful for production of reactive power needed by the converters and for the correction of power factor. There are different types of 3phase harmonic filters based on their tuning.

1) Single phase 2) Double tuned 3) high pass 4)C-type high pass.

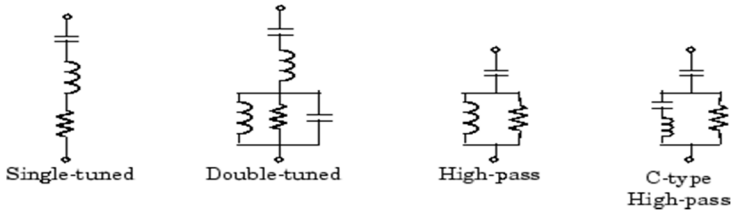


Fig.13 Filters

B. Transformer

This is basically a stationary equipment in which rotating elements are absent three phase transformer is useful to step-up and step-down the power. Here, the filtered output is given to 3 phase Step-up Transformer in order to increase the power and supplied to grid. A three-phase transformer of 100 KVA rating is used in MPPT technique the primary and secondary windings of Transformer may be connected in various connections. Different types of connections in three phase transformer are star, delta, delta lagging by 30 degrees etc.

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C. Introduction to the Grid

Grid is an interconnection of network which maintains constant power and having same impedance throughout it. It acts as a bridge between generation unit and consumption unit. A grid connected to PV system consists of solar panel, converters, inverter, filters, three phase transformer etc., with maximum power point tracking techniques. The output of the Solar Panel after certain operations connected to the utility grid.

VI. SIMULATION RESULTS

The input to the solar cell depends on two factors i.e., temperature and irradiance. The increase of temperature is measured in degree Celsius or Fahrenheit. It varies according to the time. As time changes in the morning the temperature gradually increases and as the time goes on, the temperature in the afternoon is very high as shown in graph and gradually decreases in the evening and becomes zero in the night.

The irradiance is the radiant energy, it is the intensity of light that is falling on the surface. It also varies with respect to time. Initially in the morning time it is constant for example up to 10:30, after that time it increases gradually and reaches the peak value and then decreases slowly in the evening. It units are represented in watt per meter square.

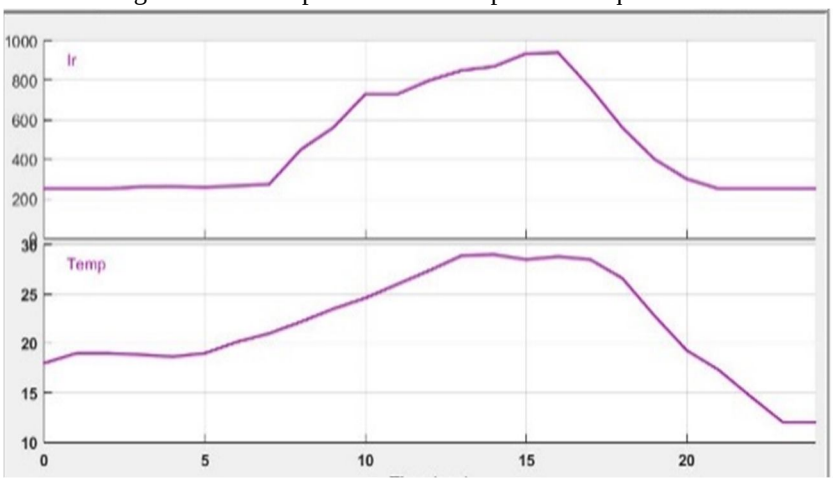


Fig.13 Input of the PV cell

A. Output of the PV cell

1) Pmean: Initially it fluctuates from 0 to some value say 25 and maintain constant until there will be some variations in the temperature and irradiance, as they increase gradually the P*mean* starts increasing and attains the maximum value and then decreases as temperature and irradiance decreases.

2) V mean: The V*mean* reaches the maximum value of 300 and fluctuates between 100 and 300 as time changes and attains the maximum value and maintain Constant value for whole time.

3) Duty Cycle: Duty cycle is the ratio of ON time period to the total time period. Duty cycle is started at the 0.5 and decreases 0.46 and maintain constant and varies slightly as input changes as shown.

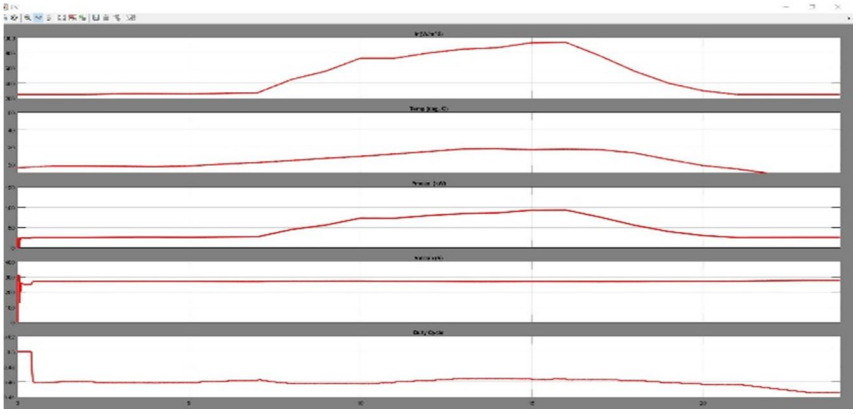


Fig.14 Different Outputs of PV cell

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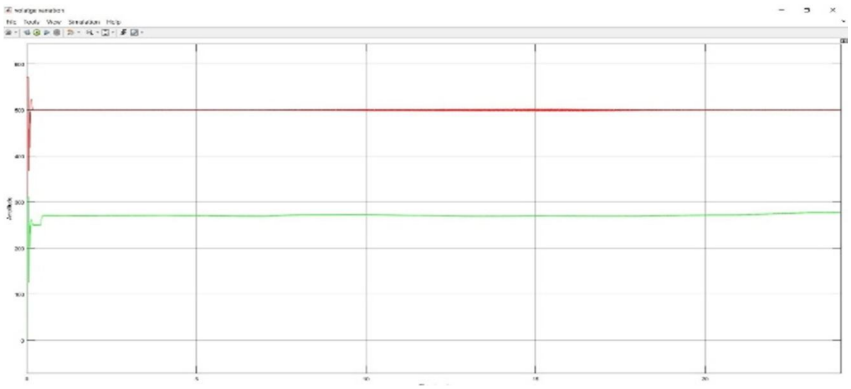


Fig.15 Output after booster converter

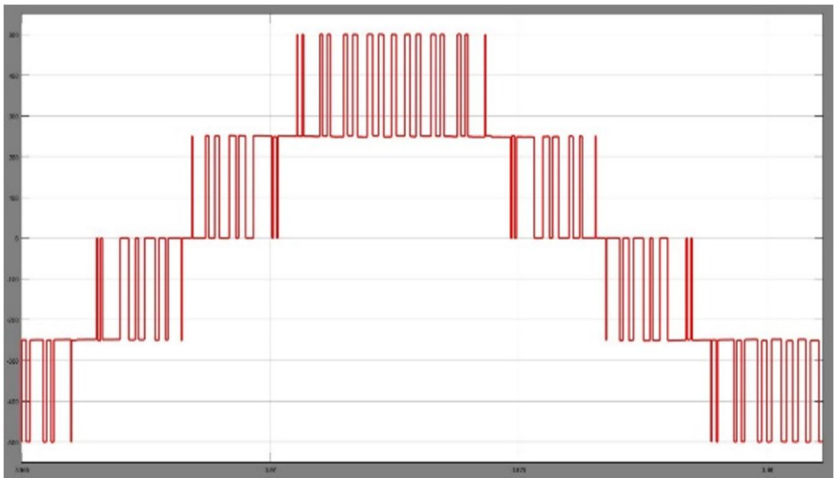


Fig.16 Inverter output

B. Grid output

Grid output consists of voltage and current waveform pure output is obtained without any fluctuations disturbances or harmonics 17 are connected to the utility grid. The output will be in the form of pure sinusoidal wave and the current waveform in the sinusoidal with reduced magnitude.

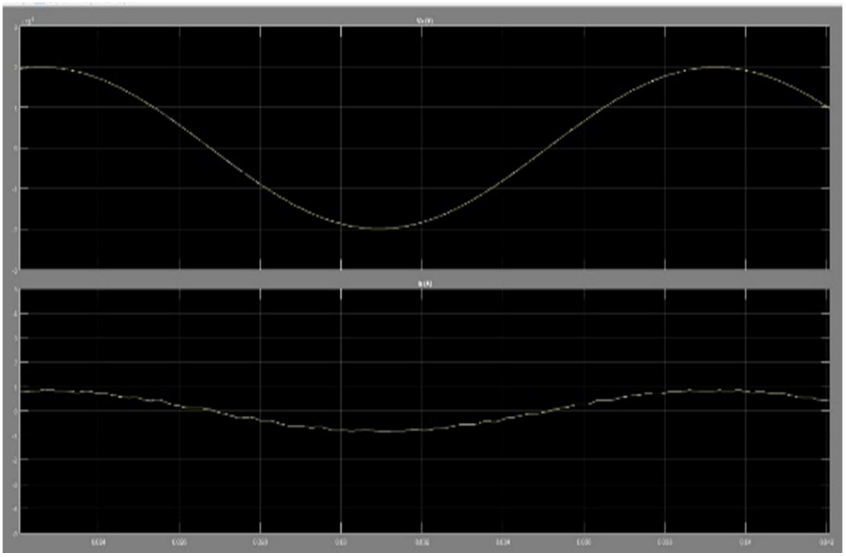


Fig. 17 Grid Voltage and Current

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VII. CONCLUSION

As the technique of MPPT is useful in determining the maximum power which can be utilized for various operations and Systems. We need to find out different techniques that are helpful in finding out the maximum power point very easily without any problems like errors in it, so we need to keep some efforts for enhancing the concept of MPPT in various systems and make the world to utilize the power only at maximum point and not to waste the power.

VIII. FUTURE SCOPE

Almost the fossil fuels are at ending stage we need to find or utilize the alternate method for producing energy. In many Industrial and commercial applications photovoltaic system is used to generate the power so it has more scope to develop in future very rapidly. By including MPPT technique with this makes the system more reliable and efficient.

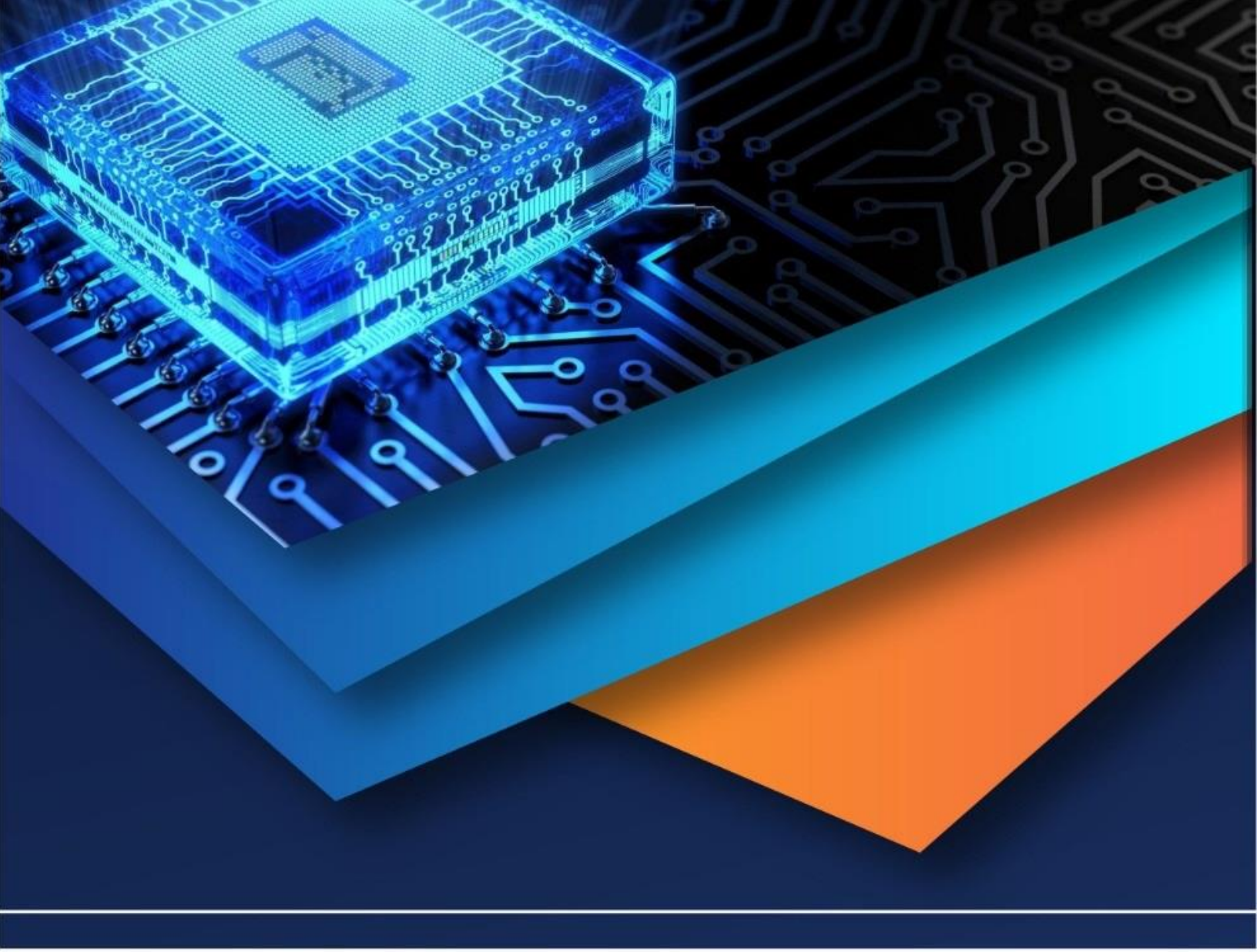
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