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Hill Climbing Algorithm based Maximum Power Tracking of a PV Array

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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, PV module, MPPT, Converter, Inverter.

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.

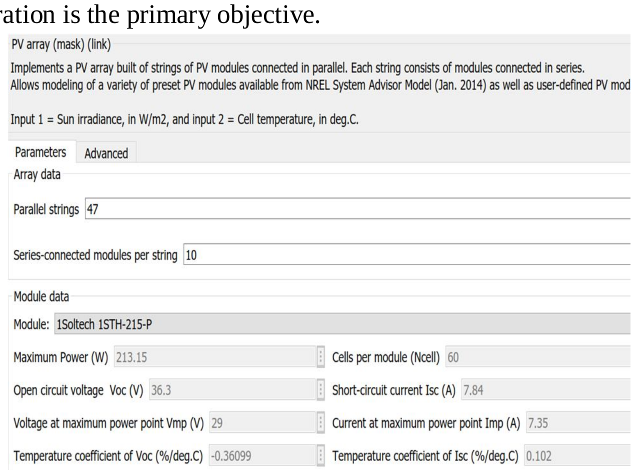

Fig .1 specifications of PV array

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B. Modelling of Solar cell

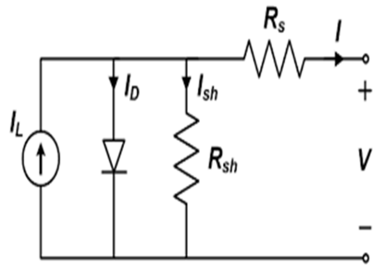

Fig .2 Single diode model of solar cell

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;

C. Graphs

The current to voltage characteristic of a solar array is non-linear, which makes it difficult to determine the MPP. The Figure below gives the characteristic I-V and P-V curve for fixed level of solar irradiation and temperature.

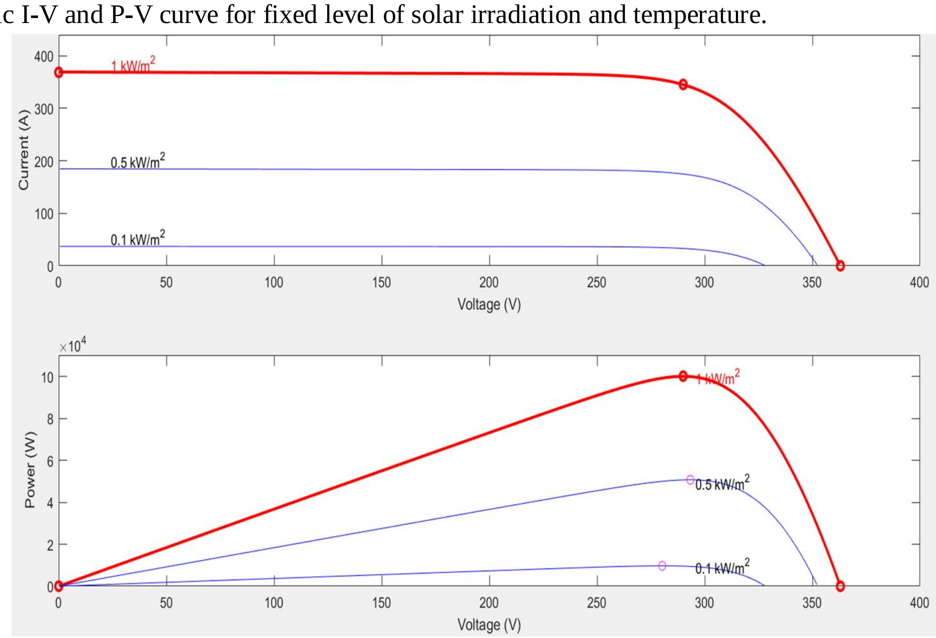

Fig .3 P-V, I-V curve of a solar cell at given irradiation

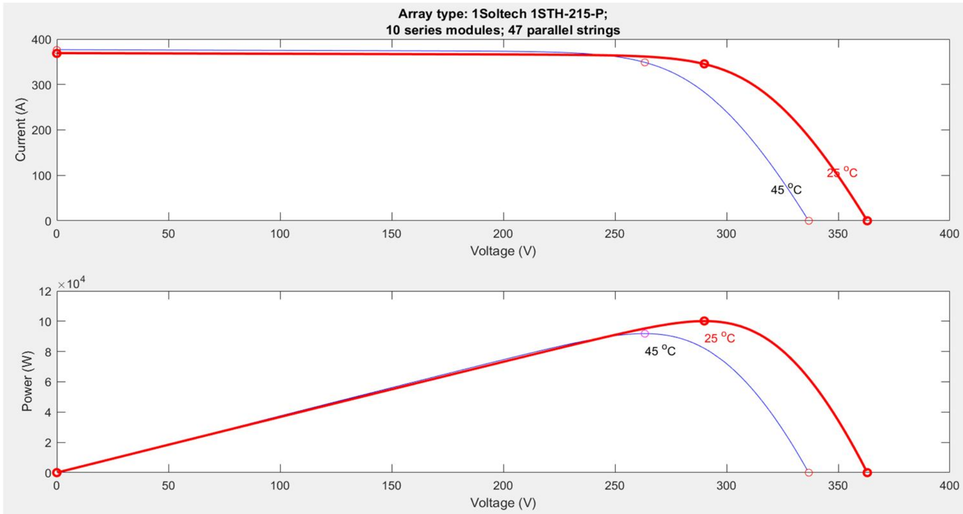

Fig .4 P-V, I-V curve of a solar cell at given temperature

II. BOOST CONVERTER

A. Circuit Diagram

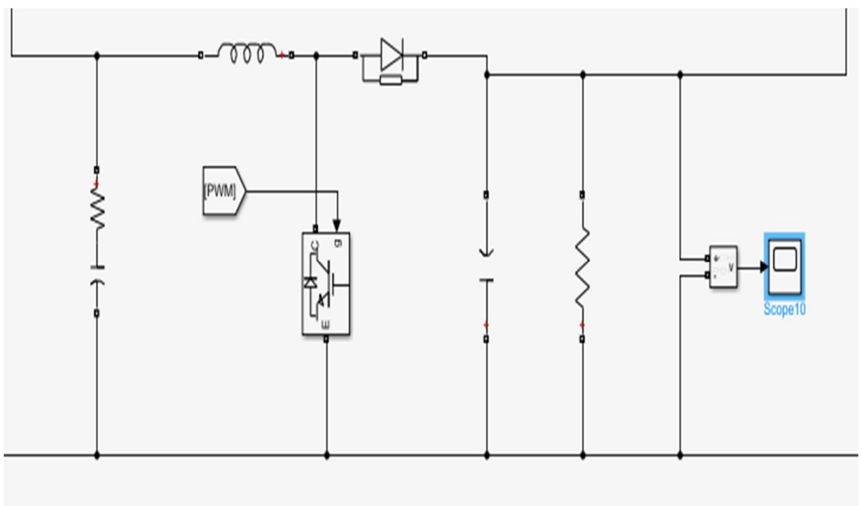

Fig .5 Circuit of boost converter

A boost converter is a step-up Chopper. It converts power from variable DC to fixed DC. It steps up's voltage from input to load. It is a class of switched mode power supply (SMPS). Step up chopper is a static device whose average output voltage is greater than input voltage.

1) Operations

There are two operations in step up chopper.

a) Charging while switch is on.

b) Discharging while switch is off.

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

A. Introduction to MPPT:

It is abbreviated as maximum power point tracking, its function is to track the maximum power point of a PV curve under different conditions such as cold weather, cloudy/ hazy days. Sometimes it is termed as MPPT algorithm. The voltage at which the panel can produce maximum power is known as maximum power point voltage as shown in the figure

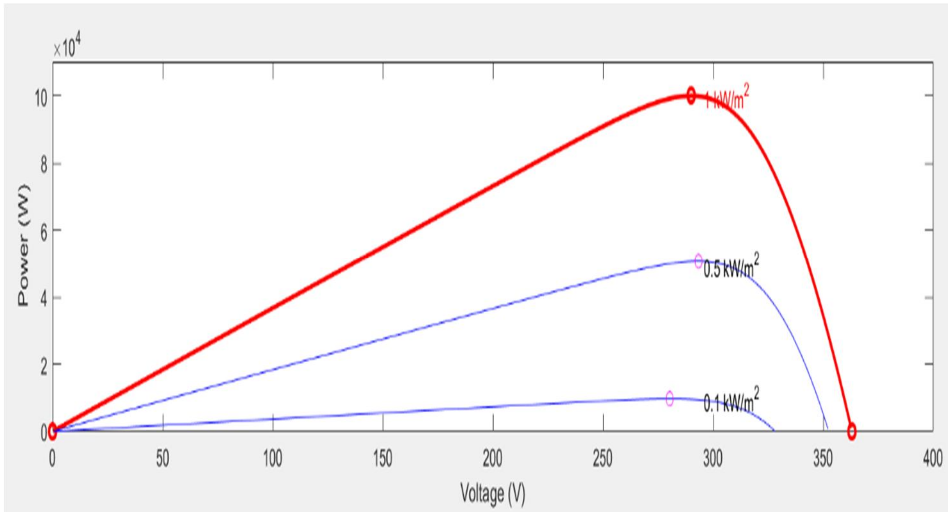

Fig .6 P-V curve of MPPT

Normally a PV module produce maximum power at 25 degrees c and the voltage will depend on the specifications of the module. The major principle as explained earlier is to track the point at which maximum power occurs by making the module to operate at efficient voltage. The voltage maintained will depend on algorithm that is being used. There are certain MPPT techniques used in general such as hill climbing algorithm, fuzzy logic based, neural network, fractional open circuit voltage method and fractional short circuit current method. fraction open circuit voltage method and short circuit current method are approximate methods because the values are predicted and are not exact. They use a constant in relation with the maximum power point voltage and open circuit voltage to predicted MPP voltage, the same will be in case of current instead of voltage they use current.

B. Hill Climbing Method

In hill climbing method we will be having perturb and observe method in addition to that we also have -Incremental conductance method, in this technique the operating point is based on our algorithm, to reach maximum power point here we move in incremental power direction or decremental power direction based on the conditions or rules specified. These are so popular methods because the reason for this is the ease of implementation and better performance when the irradiation is constant. under normal conditions there will be one maximum in the PV curve but during shading there will be multiple maximum points, the shading is because of snow, location, self-shading.

1) *Perturb and observe method:* In this method it involves perturbation which means change in current state in operating voltage of a PV array. through the change in voltage weather in incremental way or decremental procedure it tries to achieve the maximum power point. this is also known as hill climbing method, the reason is we can figure it out by observing the graph, we came to know that it needs to climb the hill look like PV curve. This system oscillates at MPP point and reducing the perturb size leads to minimization of oscillation. It in turn slows down the MPP tracking. There are two techniques employed, and are shown below.
2) *P&O with fixed perturb size:* The generated reference signal is taken and the signal may be voltage or current of an array. That reference signal will be perturbated. PL controller used to control the power. For small step size, the tracker will be low and oscillations are minimized or low. In some techniques they will perturb duty ratio. PL controllers are eliminated which makes the process easier
3) P&O with variable step size: Here we will vary the step size and improve the performance. It is not truly adaptive, the reason is the step size varies in a pre-determined way. It makes the system complex, because we need to collect each value irradiance, temperature and need to generate the corresponding perturbation values for the response.

C. Flow Chart Explanation

Here will be explaining about the flowchart. The flow chart contains different blocks and directions based on the algorithm and here will be taken two inputs voltage and current, those will be instantaneous and power will be calculated based upon those two and we will be taking the cumulative voltage and current values that means the present value and the preceding value. Now the first step is to check the power, whether the power is zero or not .so that means DP which is the present power and previous power will be checked (difference of those two). If it is zero it terminates the process and starts the next iteration. The second case when it is not zero, we will be dealing with two different cases whether it is less than zero or greater than zero. If it is greater than zero then it goes to the next block where the voltage is examined if the difference of voltage is greater than zero it increases reference voltage by specified perturb value else it decreases reference. Coming to the case where the change in power is less than zero here also the same scenario is repeated. Where the change in voltage is examined and based on that change as shown the reference value is changed.

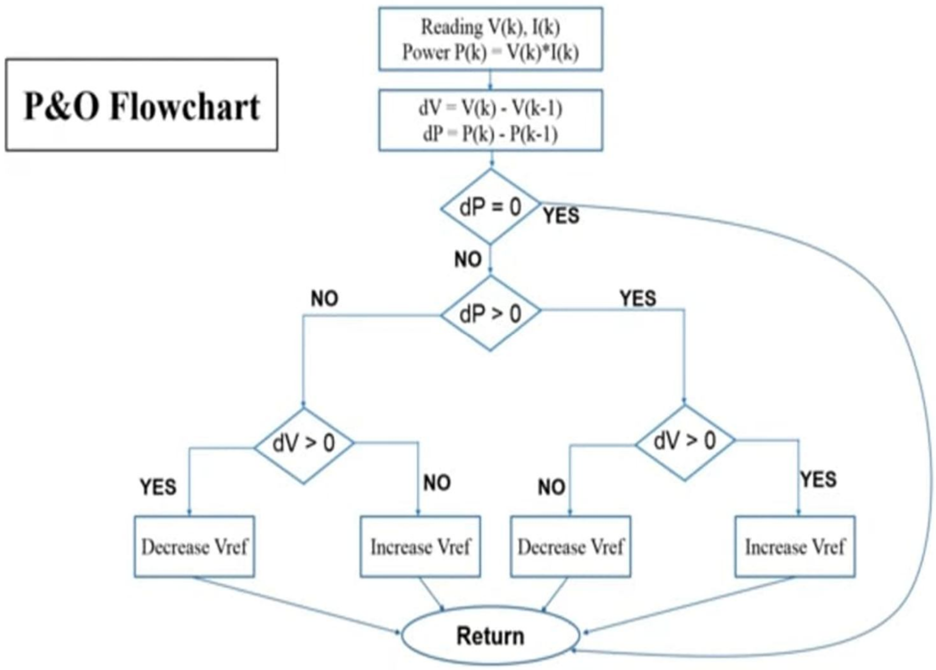

Fig .7 Flow chart of Perturb & Observer method

D. Code

The code is almost is similar as of flowchart and it is constructed based on the flow chart. Here the output will be the function of input which is represented by the first line. Here we will be initializing variables and we will follow certain rules same as in flow chart.The maximum reference voltage value is the open circuit voltage of PV array, the initial reference voltage will be the maximum power point voltage and the delta reference voltage is the value of perturbation.

```
function Vref = RefGen(V,I)
 Vrefmax = 363;
Vrefmin = 0.0;
Vrefinit = 290;
deltaVref = 1;
 persistent Vold Pold Vrefold;
 dataType = 'double';
 if isempty(Vold)
    Vold =0;
    Pold =0;
    Vrefold = Vrefinit;
 end
 P = V*I;
```

```
dV = V- Vold;
dP = P- Pold;
 if dP ~= 0
   if dP<0
       if dV<0
         Vref = Vrefold + deltaVref;
       else
          Vref = Vrefold - deltaVref;
       end
   else
       if dV<0
          Vref = Vrefold - deltaVref;
       else
          Vref = Vrefold + deltaVref;
       end
   end
else
   Vref = Vrefold;
end
if Vref >= Vrefmax | Vref <= Vrefmin
   Vref = Vrefold;
end
Vrefold = Vref;
Vold = V;
Pold = P;
```

IV. SIMULATION LINK MODEL

A. Explanation of Simulation Model

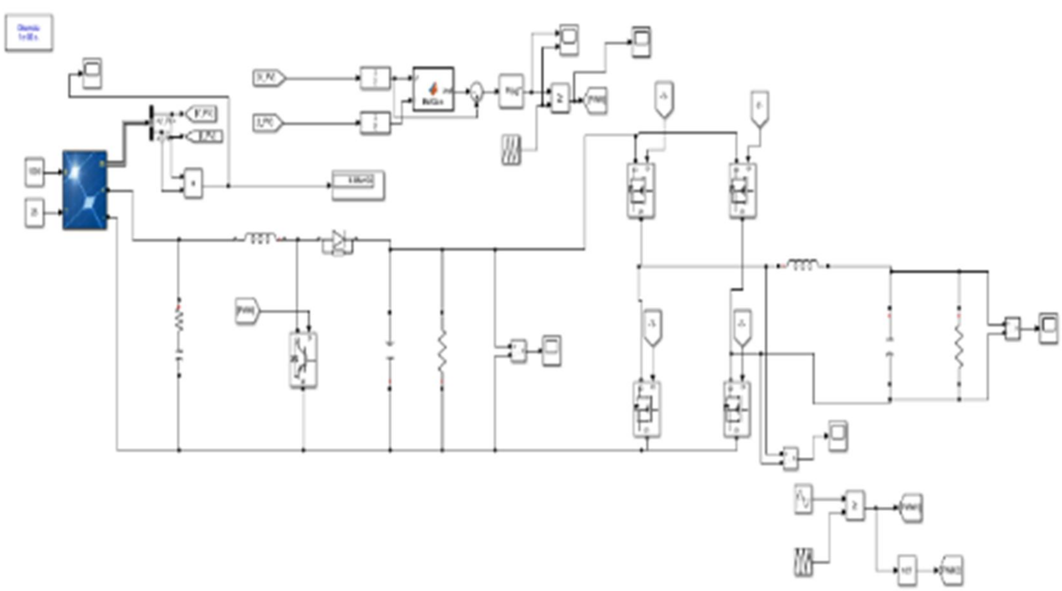

Fig .8 Model of solar cell with boost converter and MPPT system

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The input to the solar power panel will be irradiance and the temperature is at 25°C here the irradiance is constant that is 1000 W per meter square and the output will be given to the boost converter. where it steps up the DC voltage. The operation of booster converter will be of two stages one is during the switch is on and the other is during off and we can term it as charging and discharging mode .so whenever the switch is open that means the PWM is off for the switch, then the capacitor which is shown at the starting stage will act as constant voltage source which will charge the inductor that is placed next to it as positive on the left side and negative on the right side and the diode which is shown right next to the inductor will be open circuited because the negative charge will be applied on the positive set of the diode, that means that it will be open circuited. During the closing of the switch the inductor will discharge and the diode will be short circuited, the amount of voltage will be doubled at the output of the chopper and in the upper part of the circuit will be dealing with the voltage and current of the panel after the multiplication of the former parameters we will obtain the maximum power that is 100 kilowatt and in the graphs that are being demonstrated in the first section will be shown will be showing the maximum power point corresponding to the PV graph and the voltages and current will be taken as inputs to the MATLAB function.

That MATLAB functions will be having the code same as in the earlier sections and there will be given through a delay because in order to take the preceding value and succeeding as well or two consecutive values. Now in the MATLAB function the code the code will be executed as per the conditions, through that we are going to generate a reference voltage. The reference voltage will be compared with the PV panel voltage, the result will be an error signal. The error will be given to the PI controller, the output signal will be compared with the repeating sequence in order to have the saturation through the usage of relational operator PWM is generated. The PWM signal will be given as input for the switch. Coming to the inverter operation here will be having four switches those are MOSFETS and for each to be precise for two oppositely looking like switches we will be giving a different PWM and that technique is in the below part, here will be taking a sine wave and a carrier signal both will be compared and depending on the relational operator the PWM output will be generated the operation of inverter is explained further and after using the filter we will get a sinusoidal signal after filtering the inverter output.

V. INVERTER

A. Single Phase full Bridge Inverter

1) *Construction:* Inverter consists of four choppers, each of chopper consists of a pair of transistors or a thyristor and a diode. Diode connected parallel to each thyristor or switch as shown in the circuit diagram .so there are four switches in single phase full bridge inverter in which the load is connected in between the middle points of four switches S1, S4 and S2, S3. DC supply is given as input to full bridge inverter produces a square wave as output which is in AC form. The basic purpose of inverter is to convert from DC to AC. It acts like a switching device turning on and off of the switches in the inverter in a particular sequence or manner the output is obtained i.e., vdc, - vdc, 0.

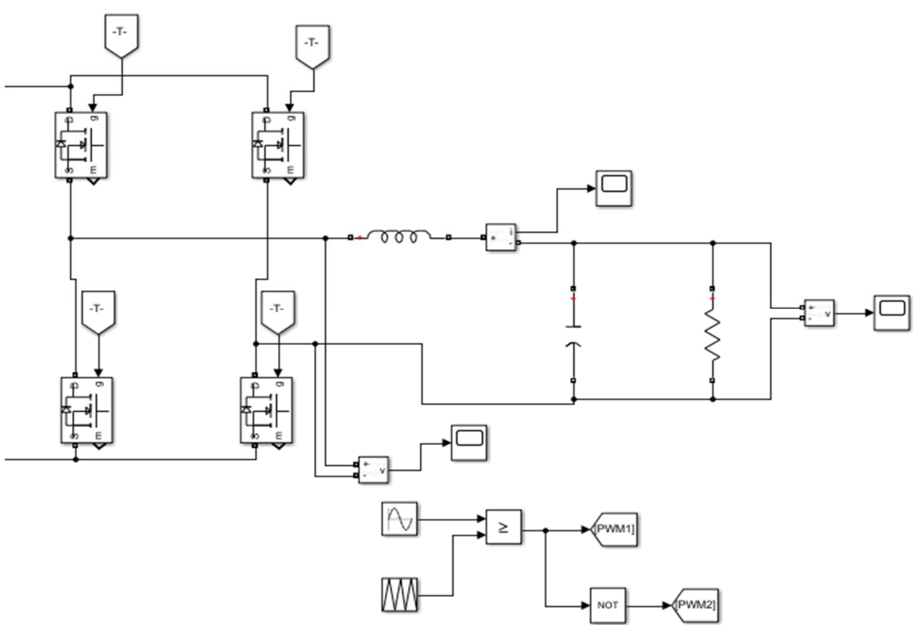

Fig .9 Inverter circuit diagram

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B. Operation

whenever the supply is given for a period of 0 to pi /2, the switches S1 and S2 gets ON, where as S3 and S4 remains OFF and the output voltage is equal to the applied voltage vs. Similarly for a period of pi/2 to pi the switches S3 and S4 gets ON and the S1 and S2 turn OFF .so the output is obtained across the load which is equal to the applied voltage but with negative polarity. This wave forms continuous so that the overall waveform looks like square wave and the output current will be same in the shape of the output voltage with reduced magnitude of the applied voltage i.e., Vs/R (this is for R-load). In the case of the RL load the waveform changes to triangular wave and in case of RLC load it is in the shape of sine wave but it depends upon the damping factor. If the damping factor is greater than 1, then the waveform will be inductive in nature which is lagging known as over-damped here XL > XC. If the damping factor is less than 1, then the waveform will be capacitive in nature which is leading this is underdamped case. In this case Excel is XL<XC. Here is the output of the booster converter which is in the form of DC is connected to inverter for the purpose of converting it into AC. The output of inverter is connected with the filter for the purpose of removing the harmonics and some unwanted signals.

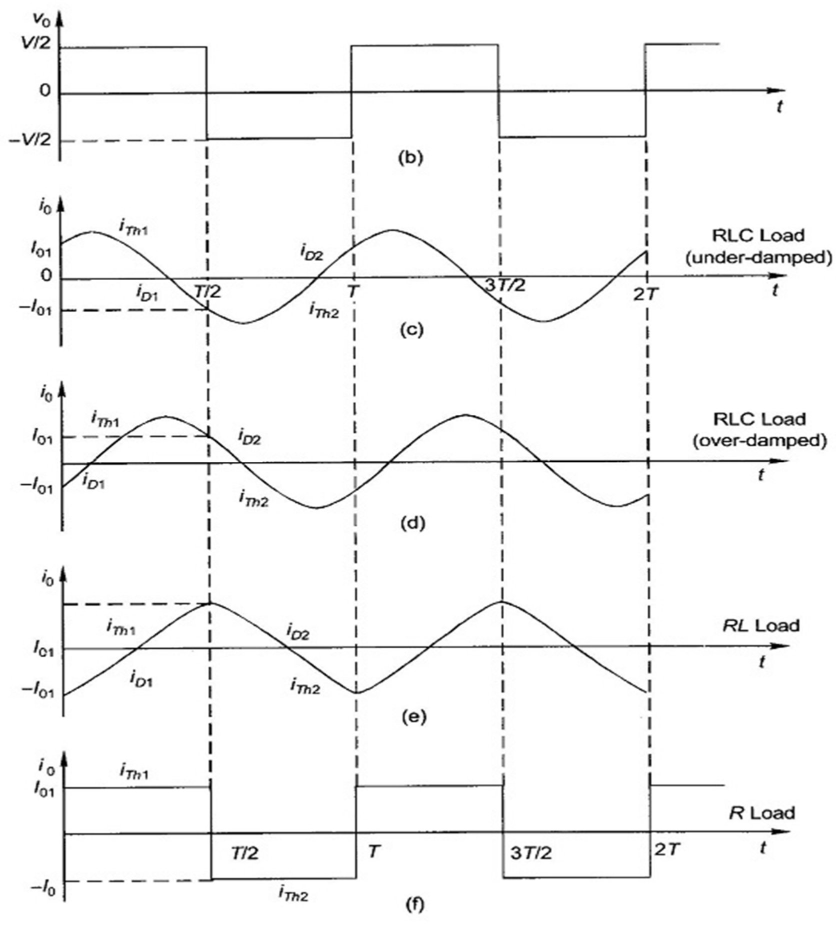

Fig .10 Output Waveforms of Full bridge inverter

C. Operation of Filter

Input to the filter is square wave, during ON or High state of square wave both the capacitor and inverter charges based on the L and C values. In this condition, if the frequency of the square wave is at resonance, the waveform goes to its peak value of square wave. During its OFF or low state of the square of the capacitor and inductor starts to discharge from maximum value of LC to the load resistor value, until it reaches the value of lower peak value of square wave. For this approach low pass filter also called as pi filter, these filters are used to modify the signals. ex: drive signals

VI. PWM AND PI CONTROLLER

A. Pulse width Modulation Techniques in Inverter

In this circuit, PWM technique is used in inverters to give a study output voltage independent of the load applied. The advantages of the PWM to reduce the switching losses and reduce voltage drop across the switch. Majority of the circuits in power electronics can be controlled by using PWM signals.

Different types of PWM techniques

1) Simple PWM
2) Multiple pulse width modulation
3) Sinusoidal pulse width modulation
4) Modified sinusoidal pulse width modulation

Pulse width modulation techniques are mostly used in AC drives for the control of speed where drive speed is dependent on frequency of applied voltage. In the circuit two signals are compared they are sine and triangular waves. If the Sine wave is greater than or equal to the triangular wave then the pulse width modulation-1 is activated otherwise the Pulse width modulation-2 is activated.

B. PI Controller

Proportional plus integral controller generates an output signal which is proportional to both input signal and integral of input signal. MPPT generates the reference voltage **V**ref and is compared with the solar cell voltage .so that some error signal. The generated error signal is given to PI controller. So that the PI controller changes the duty cycle. Here in this controller the proportional gain is represented by Kp and integral gain is represented by **K**i. By choosing appropriate values of **K**p and **K**i the desired response can be obtained. The Pi controller is activated when power is given to boost converter from PV module. The PI controller changes the duty cycle that change the value of input which can be sensed by the PI controller.

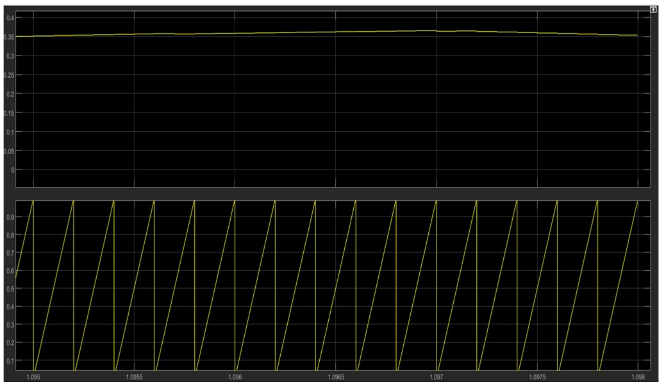

Fig .11 PI controller waveform and repeating sequence wave

Here we are getting two wave forms one is from the PI controller and the second is from repeating sequence. These two will be compared using a logical operator and the output will be based upon the logic we have used and it generates the pulses which is shown in below figure.

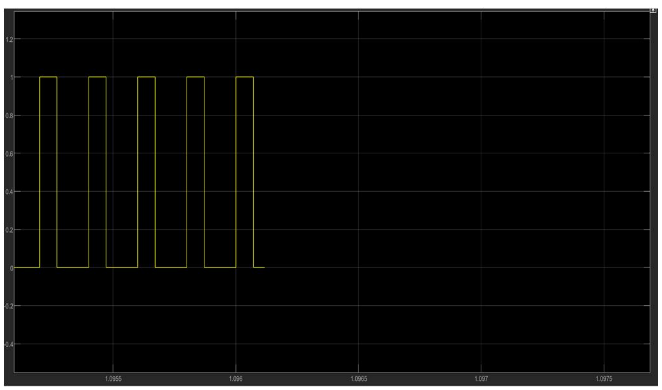

Fig .12 waveform of generated pulses

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VII. SIMULATION RESULTS

A. Output of the MPP

Output of MPP is in DC form. Initially it is obtained between 0 to 100 KW and it is fluctuating. The output is sticked to a constant value of 100kw with some small deviations in it this is the output of the MPP.

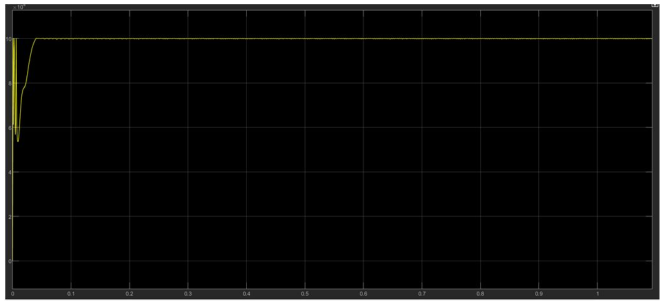

Fig .13 Output of MPP

B. Booster Output

Here we are using booster converter so the voltage will be step-up as shown

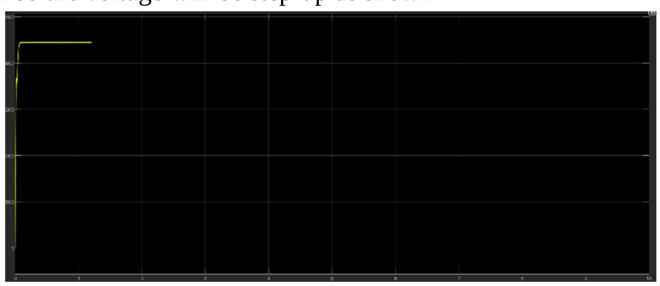

Fig .14 output of Booster converter

C. Inverter Output (Before Filtering)

Output of the inverter looks like a square wave with peak-peak amplitude of 900 volt having positive amplitude of +450 and negative amplitude of -450 V. This is the output obtained before giving output of inverter to filter.

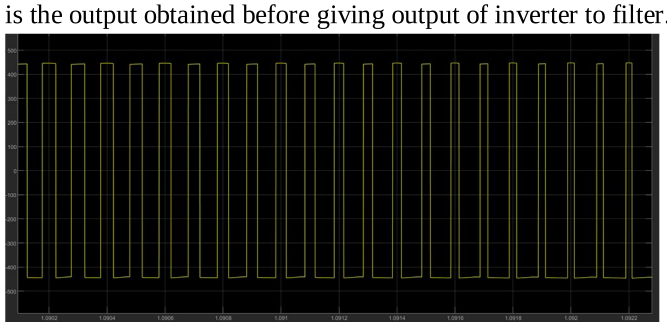

Fig .15 Output of Inverter before giving to filter

D. Final output (After Filtering)

The output of inverter by using LC filter is shown here, the output in the square wave is converted to sine wave with LC filter obtaining an amplitude of 400 volt.

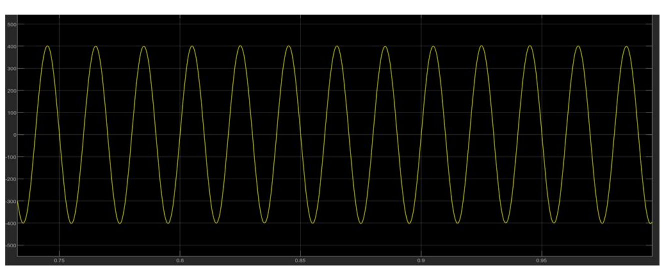

Fig .16 Output of Inverter after filtering

VIII. CONCLUSION

we conclude that as the cost of generating energy by using non renewable energy sources is very high we need to generate the power with the less cost with high efficiency .so in order to improve the efficiency with less cost of input it is possible only with the renewable energy sources like solar and wind energy. But the cost of installation of wind plants is very high. we have gone for solar plants in order to obtain the maximum efficiency from the photo voltaic cell. Here there is a need of MPP tracker to obtain the maximum power. MPPT controller of Hill Climbing algorithm is used to track the maximum power output from the panel with the main consideration of accuracy and time.

IX. FUTURE SCOPE

MPPT techniques are many types, each of its technique has some disadvantages based on the type of components used i.e., fluctuations in output.so future scope is to eliminate them by using advanced techniques.

A. Different types of controllers can be designed to improve performance of the MPPT algorithm.
B. The model reference adaptive controller MRAC can be coupled with the beta algorithm so that the maximum power can be tracked with more efficiency and tracking is improved.
C. The efficiency of tracking is less in perturb and observe method it can be improved by incremental conductance method so that dynamic response is also increased.

X. ACKNOWLEDGEMENT

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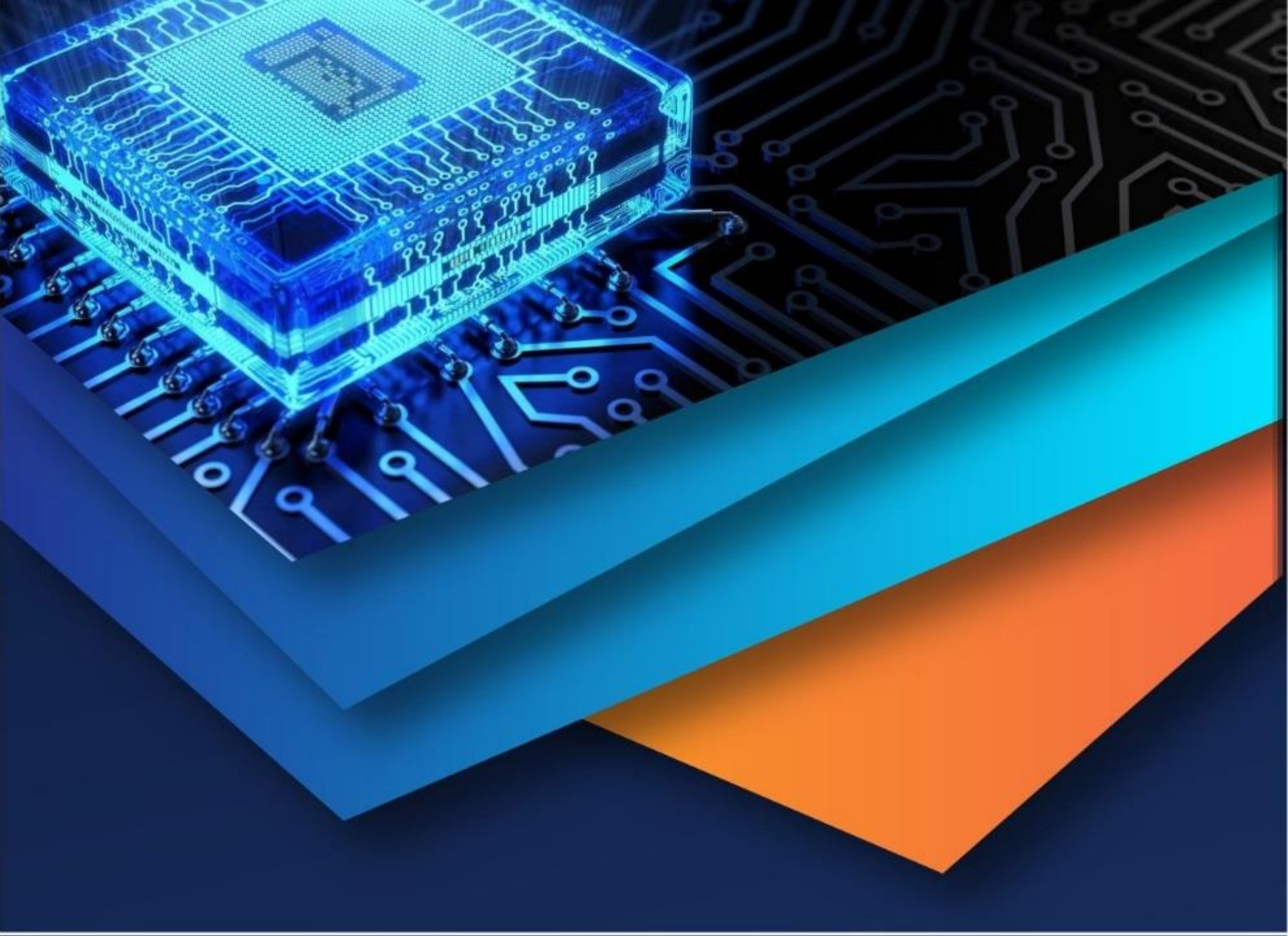

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