Simulation of Solar MPPT with Boost Converter

T.Suneel[1], Giridhar Boyina[2], G.Subba Reddy[3]
[1]Assistant Professor, EEE Department, V R Siddhartha Engineering College
[2]Software Engineer, Trixon Tech Solutions
[3]Assistant Professor, Aadisankara College of Engineering
[1]suneelmtech409@gmail.com, [2]giridhar.boyina@gmail.com

Abstract: Solar chargers are increasingly gaining momentum with government agencies pushing towards a greener solution through the use of energy derived from renewable sources. A solar charger mainly functions on the principle of harnessing the energy from the sun and utilizing it to supply electrical energy to devices or for charging batteries. The focus of this project is to identify how to get the maximum power out of a solar panel. Using a solar panel or an array of panels without a controller that can perform Maximum Power Point Tracking (MPPT) will often result in wasted power, which ultimately results in the need to install more panels for the same power requirement. For smaller/cheaper devices that have the battery connected directly to the panel, this will also result in premature battery failure or capacity loss, due to the lack of a proper end-of-charge procedure and higher voltage. In the short term, not using an MPPT controller will result in a higher installation cost and, in time, the costs will escalate due to eventual equipment failure. Even with a proper charge controller, the prospect of having to pay 30-50% more up front for additional solar panels makes the MPPT controller very attractive.

The Maximum Power Point Converter is essentially a DC-to-DC converter, where the DC input voltage is a solar panel. The intent of the converter is to show how to take the solar panel and generate a voltage capable of recharging a battery.

Keywords: Solar Charger, MPPT, Boost Converter, Perturb & Observe Algorithm, PWM.

I. INTRODUCTION

Due to the depletion of non-renewable sources of energy and increase in demand for electricity man has to search for alternative sources like renewable energy sources. Solar energy is one such renewable sources of energy which works on the principle of photovoltaic effect. Solar cell is the main element which converts solar energy into electrical energy. Solar cells are connected in series or parallel depending on requirement to form solar module. Solar modules are again connected in series or parallel depending on the current and voltage requirement to form solar array. Solar cell provides clean and pollution free energy unlike traditional source of energy like coal, diesel, natural gas, nuclear energy. It has certain disadvantage of low efficiency compared to other renewable sources of energy. This problem is overcome by using maximum power point tracking (MPPT) technique as discussed in this work.

The efficiency of solar array is very less under normal operating conditions and also further decreases with varying load, environmental conditions. To increase the efficiency of solar array different control algorithms called Maximum PowerPoint Tracking (MPPT) are being used now a days. The objective of all these algorithms is to match the source impedance with that of load impedance such that maximum power is delivered from the array. This impedance matching is achieved by using pulse width modulation of dc to dc converters which are used between solar array and load. One of the widely used methods for this purpose is Perturb and Observe method. This MPPT method is being implemented in analog and digital domain. Although analog method works faster, digital method is easy to implement and modify. Digital method is being widely implemented by using different types of controllers like DSP processor,

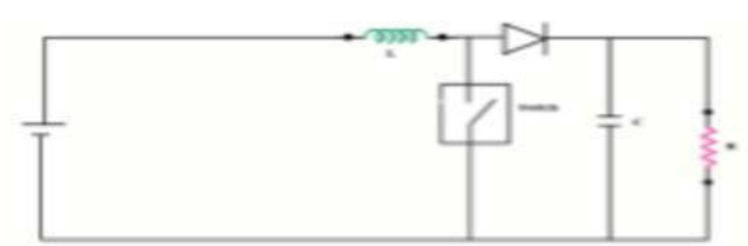
Microprocessor, Microcontrollers etc., where the MPPT algorithm is written as a coded program. However, graphical programming is simpler to understand, implement and modify. Matlab/Simulink and Lab VIEW are software's that are used to acquire data from real world, process the data and generate output that is either displayed or send to output port as control signal. In this paper, a simulation study is carried out implementing P&O method in MATLAB Simulink. Having obtained simulation results on MPPT in Simulink, the same is implemented in hardware using Lab VIEW software.

BOOST CONVERTER

A boost converter is designed to step up a fluctuating or variable input voltage to a constant output voltage of 24 volts with input range of 6-23volts in. To produce a constant output voltage feedback loop is used. The output voltage is compared with a reference voltage and a PWM wave is generated.

A DC to DC converter is used to step up from 12V to 24V. The 12V input voltage is from the battery storage equipment and the 24V output voltage serves as the input of the inverter in solar electric system. In designing process, the switching frequency, f is set at 20 kHz and the duty cycle, D is around 50%. Here we want to introduce an approach to design a boost converter for photovoltaic (PV) system using microcontroller. The converter is designed to step up solar panel voltage to a stable 24V output without storage elements such as battery. The output of the boost converter is tracked, measured continuously and the values are sent to the microcontroller unit to produce pulse-width-modulation (PWM) signal. The PWM signal is used to control the duty cycle of the boost converter. Typical application of this boost converter is to provide DC power supply for inverter either for grid connected or standalone system. Simulation and experimental results describe the performance of the proposed design.

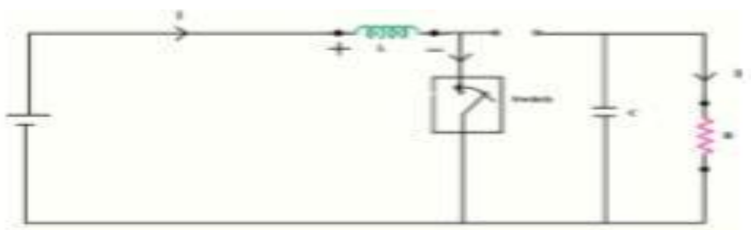
As stated in the introduction, the maximum power point tracking is basically a load matching problem. In order to change the input resistance of the panel to match the load resistance (by varying the duty cycle), a DC to DC converter is required. It has been studied that the efficiency of the DC to DC converter is maximum for a buck converter, then for a buck-boost converter and minimum for a boost converter but as we intend to use our system either for tying to a grid which requires 230 V at the output end, so we use a boost converter.



circuit diagram of boost converter

MODE 1 OPERATION OF THE BOOST CONVERTER

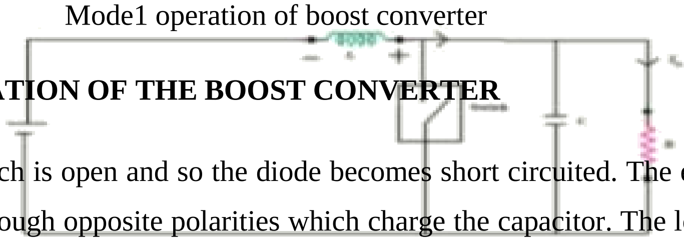
When the switch is closed the inductor gets charged through the battery and stores the energy. In this mode inductor current rises (exponentially) but for simplicity we assume that the charging and the discharging of the inductor are linear. The diode blocks the current flowing and so the load current remains constant which is being supplied due to the discharging of the capacitor.



Mode1 operation of boost converter

MODE 2 OPERATION OF THE BOOST CONVERTER

In mode 2 the switch is open and so the diode becomes short circuited. The energy stored in the inductor gets discharged through opposite polarities which charge the capacitor. The load current remains constant throughout the operation. The waveform for a boost converter are shown in figure



Mode2 operation of boost converter

Duty Cycle:

The duty cycle can be found using the following relation-

$$D=1-\frac{Vi}{Vo}$$

Inductor value:

The value of inductor is determined using the following relation

Lmin=D (1-D2)*R/2*Fs

Capacitor value:

The value of capacitor is determined from the following equation

C=D/Fs*R*Vr

Where,

C is the minimum value of capacitance
D is duty cycle,
R is output resistance,
Fs is switching frequency, and Vr is output voltage ripple factor

Charging Mode:

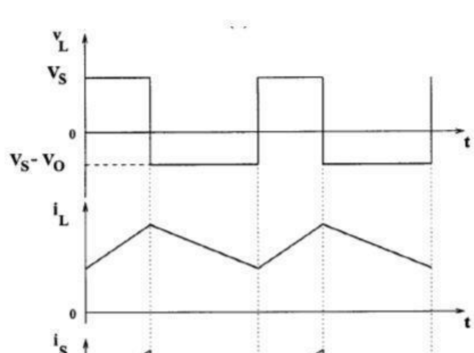
In this mode of operation; the switch is closed and the inductor is charged by the source through the switch. The charging current is exponential in nature but for simplicity is assumed to be linearly varying. The diode restricts the flow of current from the source to the load and the demand of the load is met by the discharging of the capacitor.

Discharging Mode:

In this mode of operation; the switch is open and the diode is forward biased.

The inductor now discharges and together with the source charges the capacitor and meets the load demands. The load current variation is very small and in many cases is assumed constant throughout the operation.

WAVEFORMS:



MAXIMUM POWER POINT TRACKING ALGORITHM

An Overview of Maximum Power Point Tracking

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. According to Maximum Power Transfer theorem, the power output of a circuit is maximum, when the Thevenin impedance of the circuit (source impedance) matches with the load impedance. Hence our problem of tracking the maximum power point reduces to an impedance matching problem. 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.

DIFFERENT MPPT TECHNIQUES

1) Perturb and Observe (hill climbing method)
2) Incremental Conductance method
3) Fractional short circuit current
4) Fractional open circuit voltage
5) Neural networks
6) Fuzzy logic

Characteristics of different MPPT techniques

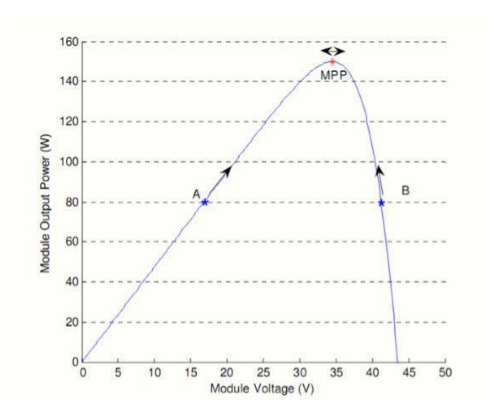
MPPT technique	Convergence speed	Implementation complexity	Periodic tuning	Sensed parameters
Perturb & observe	Varies	Low	No	Voltage
Incremental conductance	Varies	Medium	No	Voltage, current
Fractional V_{oc}	Medium	Low	Yes	Voltage
Fractional I_{sc}	Medium	Medium	Yes	Current
Fuzzy logic control	Fast	High	Yes	Varies
Neural network	Fast	High	Yes	Varies

PERTURB & OBSERVE

Perturb & Observe (P&O) is the simplest method. In this we use only one sensor, that is the voltage sensor, to sense the PV array voltage and so the cost of implementation is less and hence easy to implement. The time complexity of this algorithm is very less but on reaching very close to the MPP it doesn’t stop at the MPP and keeps on perturbing on both the directions. When this happens the algorithm has reached very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of the algorithm. However the method does not take account of the rapid change of irradiation level (due to which MPPT changes) and considers it as a change in MPP due to perturbation and ends up calculating the wrong MPP. To avoid this problem we can use incremental conductance method.

Details of Perturb & Observe Algorithm

The Perturb & Observe algorithm states that when the operating voltage of the PV panel is positive, then we are going in the direction of MPP and we keep on perturbing in the same direction. If p is negative, we are going away from the direction of MPP and the sign of perturbation supplied has to be changed.



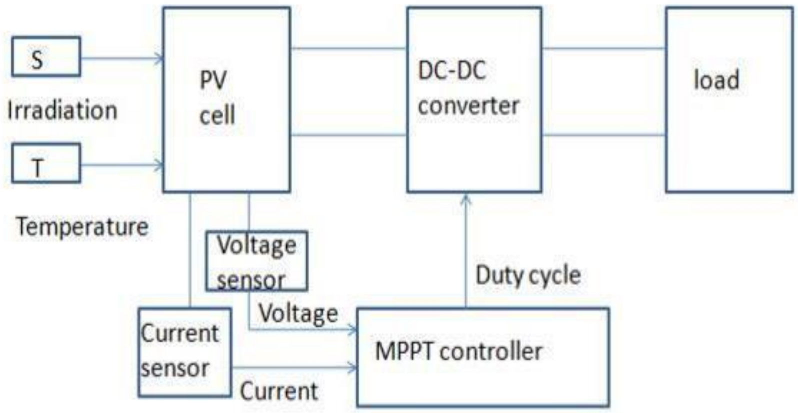
Solar Panel Characteristics Showing MPP and Operating Points A and B

Figure shows the plot of module output power versus module voltage for a solar panel at a given irradiation. The point marked as MPP is the Maximum Power Point, the theoretical maximum output obtainable from the PV panel

Consider A and B as two operating points. As shown in the figure above, the point A is on the left hand

side of the MPP. Therefore, we can move towards the MPP by providing a positive perturbation to the voltage. On the other hand, point B is on the right hand side of MPP. When we give a positive perturbation, the value of P becomes negative, thus it is imperative to change the direction of perturbation to achieve MPP.

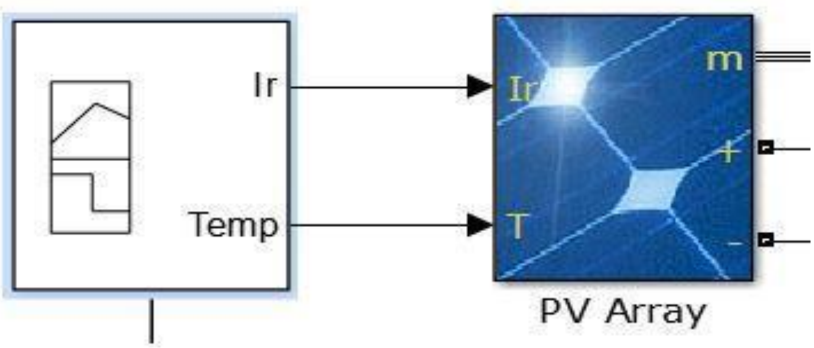
Flow chart of perturb and observe



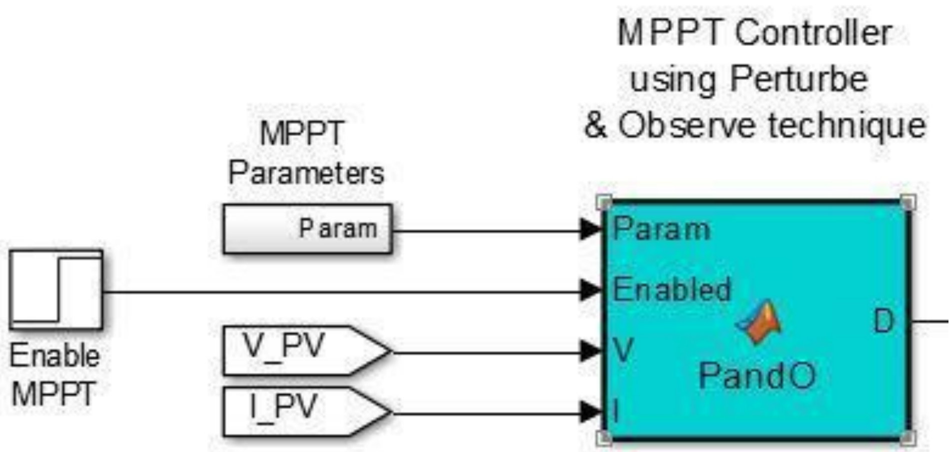
Block diagram of PV cell with MPPT controller

SIMULATION OF MPPT

SIMULINK BLOCK OF SOLAR PV ARRAY



SIMULINK MODEL OF PERTURB & OBSERVE



PROGRAM FOR P&O:

```
function D  = PandO(Param, Enabled, V, I)
%  MPPT controller based on the Perturb & Observe algorithm.
%  D output = Duty cycle of the boost converter (value between 0 and 1)
%  Enabled input = 1 to enable the MPPT controller
%  V input = PV array terminal voltage (V)
%  I input = PV array current (A)
%  Param input:
Dinit = Param(1);
%Initial value for D output Dmax = Param(2);
%Maximum value for D Dmin = Param(3);
Minimum value for D
deltaD = Param(4); %Increment value used to increase/decrease the duty cycle % ( increasing D
= decreasing Vref )
persistent Vold Pold Dold;
dataType = 'double';
if isempty(Vold)
    Vold=0;
    Pold=0;
    Dold=Dinit;
end
P= V*I;
dV= V - Vold;
dP= P - Pold;
if dP ~= 0 & Enabled ~=0
    if dP < 0
        if dV < 0
            D = Dold - deltaD; else
            D = Dold + deltaD; end
    else
        if dV < 0
            D = Dold + deltaD; else
            D = Dold - deltaD; end
    end
else D=Dold; end
if D >= Dmax | D<= Dmin D=Dold;
end
Dold=D;
```

Vol. 5, Issue. 3, 2018, ISSN 2349-0780

```
Vold=V;
old=P;
```

Vol. 5, Issue. 3, 2018, ISSN 2349-0780

COMPLETE MODEL OF PV PANEL WITH MPPT

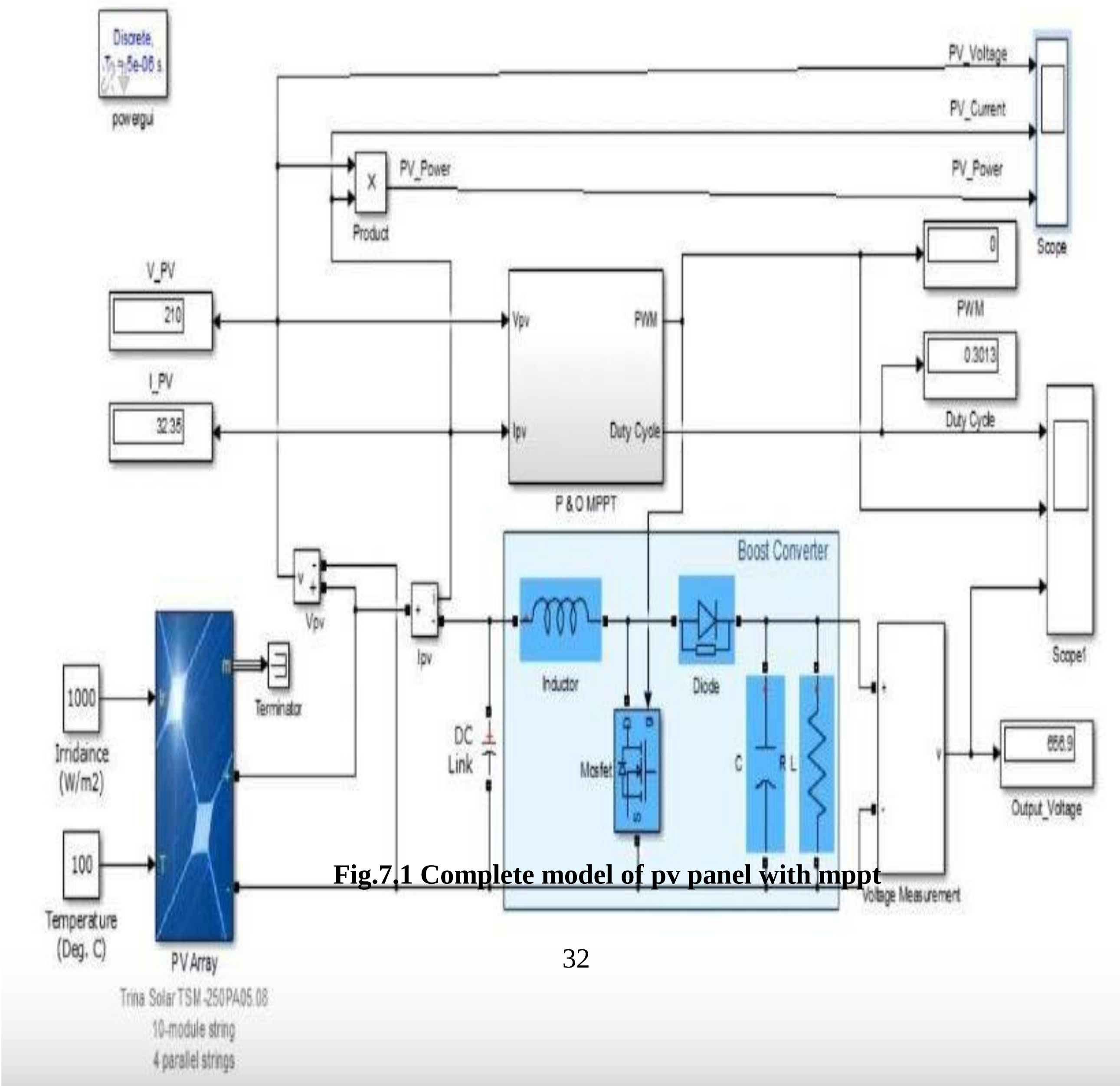
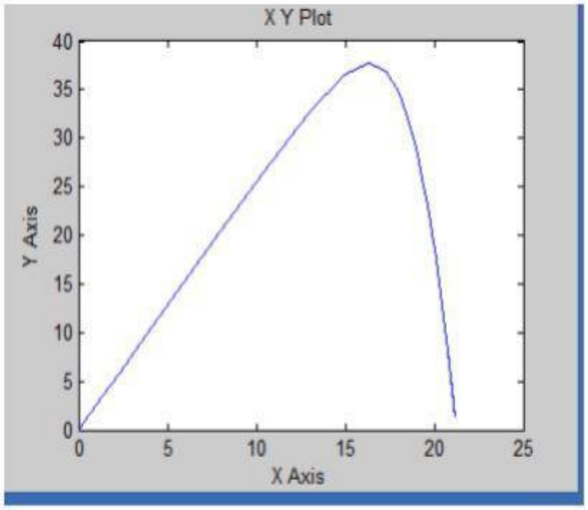
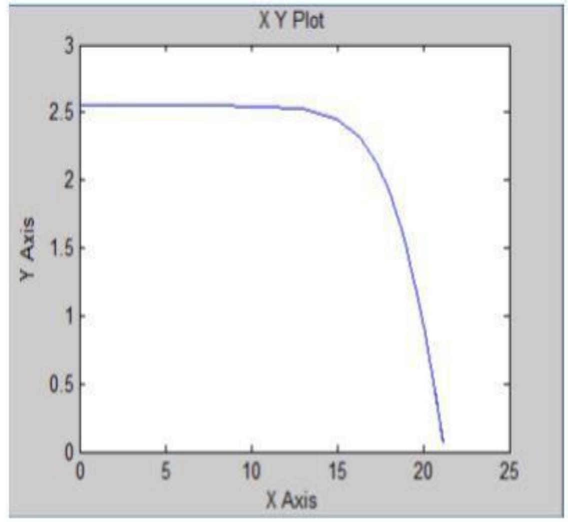


Fig.7.1 Complete model of pv panel with mppt

32

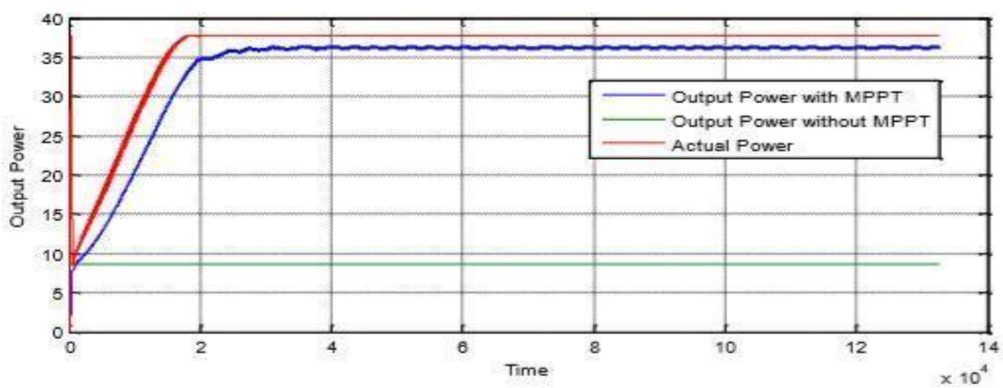
SIMULATION RESULT FOR SOLAR PANEL





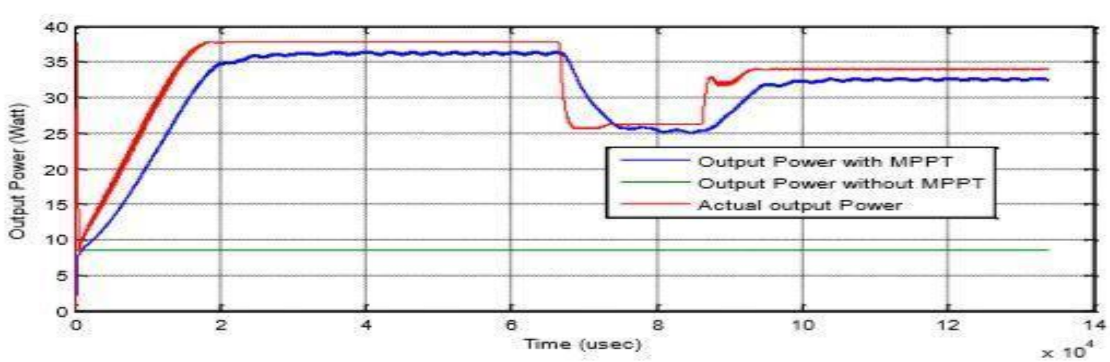
P-V characterstics of solar panel **I-V characterstics of pv panel**

CASE I: Output Power at Constant Irradiation (1000W/m2)



Above graph shows that when we are using MPPT and taking irradiance is constant then the power become increased.

CASE II: With Varying Irradiation



CONCLUSION

The work done in this project can be implemented to track the maximum power point of solar array under varying weather conditions using LabVIEW. MPPT of solar array cannot be implemented under partial shaded conditions using INC method. Module integrated converters has to be used to track MPPT under partially shaded conditions.The maximum power point of solar array can be rapidly tracked by using perturb and observe method under normal and also varying weather conditions. In the hardware implementation of MPPT the pulses given to MOSFET are not exactly square wave at lower value of duty cycles so the power is not becoming zero at lower duty cycles .In order to avoid that voltage driver circuit has to be used. In this work MPPT is implemented by considering the maximum power

REFERENCES

[1] N. Pandiarajan and Ranganath Muth" Mathematical Modeling of Photovoltaic Module with Simulink" in 2011 1st International Conference on Electrical Energy Systems.
[2] Alpesh P. Parekh, Bhavarty N. Vaidya and Chirag T. Patel"Modeling and Simulation Based Approach of Photovoltaic System" in Global Research Analysis Volume 2 Issue 4 April 2013 • ISSN No 2277 – 8160.
[3] Pandiarajan N, Ramaprabha R and Ranganath Muthu" Application Of Circuit Model For Photovoltaic Energy Conversion System".
[4] G. Venkateswarlu and Dr.P.Sangameswar Raju" Simscape Model Of Photovoltaic Cell" in International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 2, Issue 5, May 2013
[A]http://en.wikipedia.org/wiki/Photovoltaics
[B]http://www.japanfs.org/ja/files/Stand-Alone_PV_Modules.jpg

AUTHORS

[1]**T.Suneel** received his Bachelor degree in Electrical and Electronics Engineering from Gudlavalleru Engineering College, Gudlavalleru (INDIA) in 2007 and M.Tech in Power Electronics and drives from VIGNAN Engineering College, JNTU University Kakinada, (INDIA) in 2009. He is currently working as an Assistant Professor in Electrical and Electronics Engineering Department at V.R.Siddhartha Engineering College Vijayawada, (INDIA). His research interests include Power Electronics, Power Electronics Drives and Power Systems.

[2]**Giridhar Boyina** received his Bachelor degree in Electrical and Electronics Engineering from V.R.Siddhartha Engineering College Vijayawada, (INDIA) in 2012 and Master of Science in Software Engineering from Jawaharlal Nehru Technological University, Hyderabad (INDIA) in 2015. He is currently working as a Software Developer in Trixon Tech Solutions Hyderabad, (INDIA).His research interests include Power Systems, Data Structures, Algorithms and Software Engineering.

[3]**G.Subba Reddy**, working as assistant professor in Aadisankara College of Engineering and Technology, Gudur (INDIA) since 24th June 2013 and having

experience of 9 years in teaching starting from 24th June 2009 to till date. His research interests include Power Electronics, Power Electronics Drives and Power Systems.