Analysis of PV Array Solar Energy Using Advanced Hill Climbing Controller

Davish Meitei Thongam, Namita Jaiswal

***Abstract*— Solar Photovoltaic systems are used worldwide to utilize energy of sun for power generation during recent years. The objective of this paper is to evaluate in detail the concepts of maximum power point tracking (MPPT) techniques which is used for the available solar energy at a particular place needs to be utilized by a photovoltaic systems to maximum extent. In this paper the advanced hill climbing techniques is used for MPP of solar energy. This technique increases efficiency of photo voltaic systems due to which this technique play an important role. This technique includes both Perturb & Observe method and Incremental Conductance method. In the present study, a review of AdvancedHill Climbing MPPT techniques, has been carried out with detailed flowcharts of algorithms is easier, not expensive which would lead to increase in PV power generation.**

***Index Terms*— MPPT; PV Array; Perturb and Observe (PO); Solar Energy, Hill Climb Controller.**

I. INTRODUCTION

In power sector, one of the major concerns is the day-to-day increasing power demand. But to meet this increasing demand using the conventional energy sources along with conventional energy generation systems is getting difficult. So the demand for renewable resources of energy has increased very much. Renewable sources like wind energy and solar energy are the prime energy sources which are being utilized in this regard. But on the other hand, the continuous use of fossil fuels has been reducing the fossil fuel reserves as well as causing disastrous effects on the environment. It is increasing global warming and depletion of the biosphere in cumulatively way.

Solar energy is a clean and renewable energy resource for power generation. The power output from a solar photovoltaic system mainly depends on the nature of the connected load because of non-linear I-V characteristics.

The PV systems connected directly to the load result in overall poor efficiency as such MPPT is to be introduced in PV systems to increase the efficiency of the system [1]. Solar radiation, load impedance and module temperature are the three factors which affect the maximum power extraction from solar PV module. I-V curve of PV module is a function of insolation and temperature which affects output current and voltage.

In this paper, a simulation and experimental study of Advanced Hill climbing MPPT algorithm is developed to maximize the power of a solar generating system. This objective is achieved by modulating the pulse width of the switch control signal (increasing or decreasing the duty ratio of the switching converter). The rest of the paper is organized as follows. The dynamic model of the solar generating system is described in Section II. In Section III, the MPPT technique is introduced. In Section IV, an advanced hill climb technique is described. Simulations results, experimental results and conclusion are presented in Section V and VI respectively. Circuit simulations for the complete system are successfully verified in the MATLAB.

II. PV CELL

Solar cell panel works on the basis of Photo voltaic effect. A solar cell consists of a semi-conductor where the front and reverse side have been processed (doped) so that the front side normally has a surplus of free electrons while the reverse side has a deficit.[3] Bound electrons in the solar cell can absorb a photon and thereby become mobile. Most of them will be caught by the field in the interface and transported to the front side of the cells.[3] If the front- and reverse side are connected with an electrical circuit, the electron can do useful work in a light bulb, electrical motor, and computer. Solar cells give an output voltage of approximately 0.3-0.6 V, depending on the technology.

2.1 MODELLING OF PV CELL

For solar panel, a solar cell is the building block. By connecting many solar cells in series and parallel. A photovoltaic module is formed. Considering only a single solar cell; it can be modelled by utilizing a current source, a diode and two resistors. This model is known as a single diode model of solar cell. Only single diode model is considered here, but two diode models are also available.

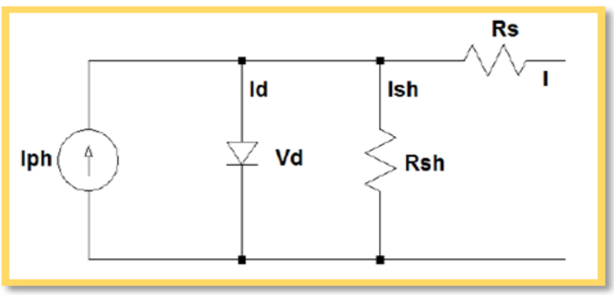

Figure 2.1: Single diode model of a solar cell

The characteristic equation for a photovoltaic cell is given by

$$I = I\lg - Ios*[\exp\{q*V+I*Rs/A*k*T\}-1]-V+I*Rs/Rsh \quad (1)$$

ISSN: 2278 – 7798

Where,

Ios = Ior∗(T/Tr)3∗[exp{q∗Ego∗1/Tr−1/T/A∗k}] **(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, $1.38 * 10^{-19}$ J/K;

q = Electron charge, $1.6*10^{-23}$ 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 module is dependent on the number of cells in parallel and number of cells in series. the current variation is less dependent on the shunt resistance and is more dependent on the series resistance as it is observed from the experimental results[7].

$$I = Np * Ilg - Np * Ios * \left[\exp\left\{q * \frac{\frac{V}{Ns} + I * \frac{Rs}{Np}}{A * k * T}\right\} - 1\right] - \frac{V}{\;}$$

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.

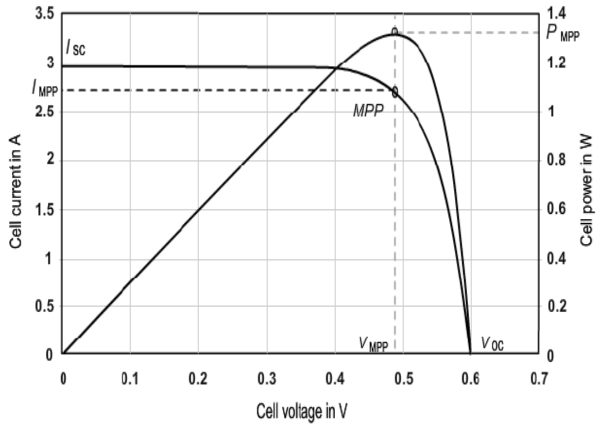

Figure 2.2: P-V I-V curve of a solar cell at given temperature and solar irradiation

2.2 EFFECT OF VARIATION OF SOLAR IRRADIATION

The P-V and I-V curves of a solar cell are highly dependent on the solar irradiation values. The solar irradiation as a result of the environmental changes keeps on fluctuating, but control mechanisms are available that can alter and change the track of the working of the solar cell to meet the required load demands. Higher is the solar irradiation, higher would be the solar input to the solar cell and hence power magnitude would increase for the same voltage value. The open circuit voltage increases with the increase in solar irradiation. This is due to the fact that, when more sunlight incidents on to the solar cell, the electrons are supplied with higher excitation energy, thereby increasing the electron mobility and thus more power is generated.

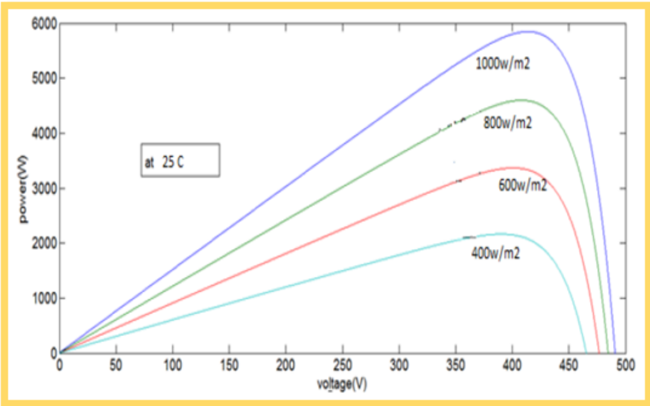

Figure 2.3: Variation of P-V curve with solar irradiation

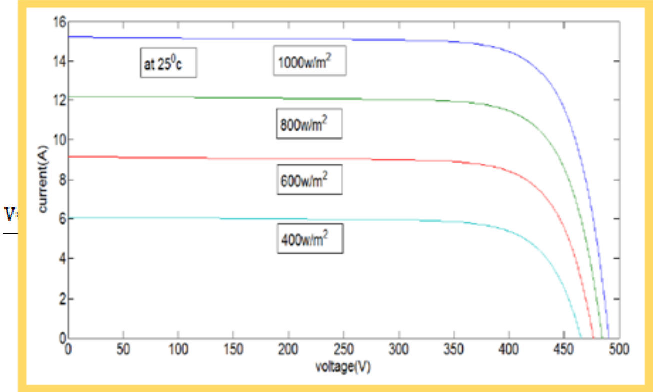

Figure 2.4: Variation of I-V curve with solar irradiation

2.3 EFFECT OF VARIATION OF TEMPERATURE

On the contrary the solar cell has a negative impact on the power generation capability as the temperature increase. Increase in temperature is accompanied by a decrease in the open circuit voltage value. More energy is required to cross this barrier as the temperature increases and thus causes increase in the band gap of the material. Thus the efficiency of the solar cell is reduced [7] and [10].

ISSN: 2278 – 7798

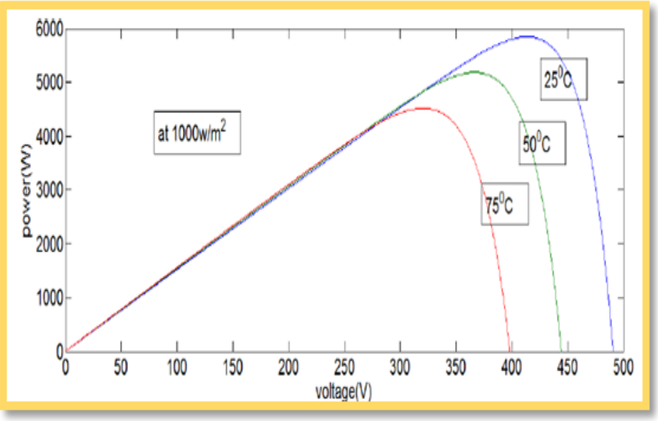

Figure 2.5: Variation of P-V curve with temperature

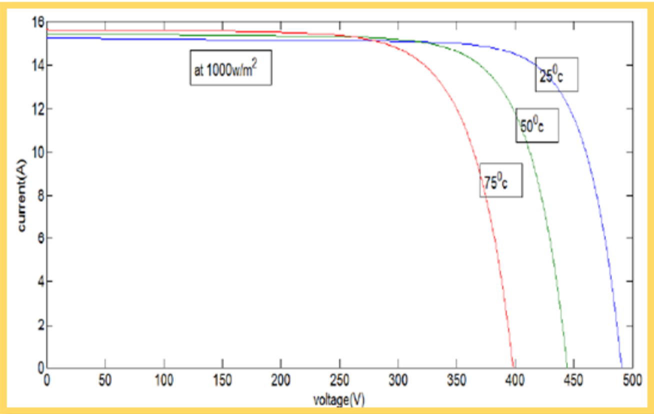

Figure 2.6: Variation of I-V with temperature

III. MPPT

Maximum Power Point Tracking, frequently referred to as MPPT, is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are capable of. MPPT is not a mechanical tracking system that "physically moves" the modules to make them point more directly at the sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power. Additional power harvested from the modules is then made available as increased battery charge current. So this technique is used to improve the efficiency of the solar panel. It is depends on 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.

3.1 Different MPPT techniques

There are different techniques used to track the maximum power point. Few of the most popular techniques are[4]:

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

IV. Advanced Hill Climb Technique

The problem considered by MPPT techniques is to automatically find the optimal point (Vmpp, Impp) at which a PV array should operate to obtain the maximum power output Pmpp under a given temperature and irradiance. Most techniques respond to changes in both irradiance and temperature, but some are specifically more useful if temperature is approximately constant. Most techniques would automatically respond to changes in the array due to aging, though some are open-loop and would require periodic fine-tuning. In our context, the array will typically be connected to a power converter that can vary the current coming from the PV array. Fig. 5.6 shows the characteristic power curve for a PV array and the optimal point.

The advanced hill climbing based algorithm consists of hybrid algorithm using a different algorithm technique along with the hill climbing method for faster and accurate tracking of MPP. The voltage and current controlled algorithms are more accurate and effective than most commonly used hill-climbing
algorithm at low solar radiation. Therefore these algorithms are combined with P&O and INC algorithms to increase their effectiveness. The hill climbing based algorithms oscillate around the MPP in slow varying atmospheric conditions.
Therefore to decrease losses due to oscillations, the hill climbing based algorithms are suitable in only rapidly changing atmospheric conditions and the constant voltage method is fast and sufficient for constant conditions. The two mode control algorithm combines these two algorithms by using incremental conductance method for more than 30% normalized solar radiation and constant voltage method for less than 30% normalized radiation. The flow chart of the algorithm of this method is shown in Fig. 4.1.

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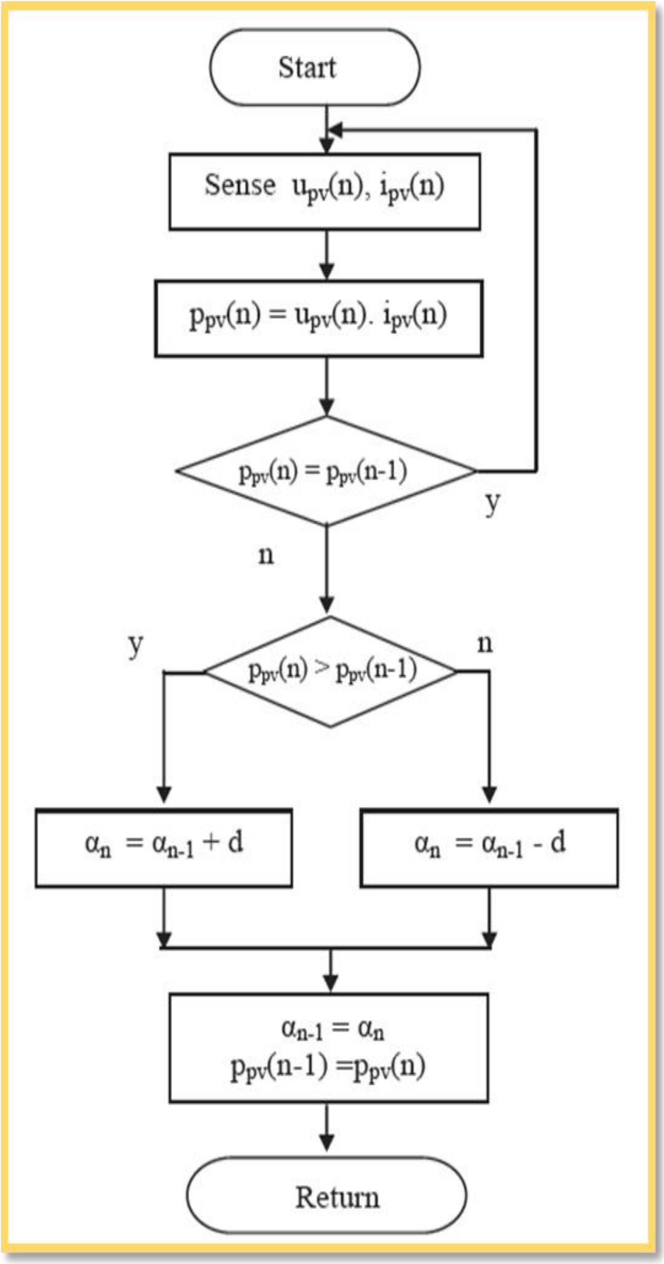

Fig 4.1. The flowchart of Advanced Hill climbing algorithm

V. Simulation & Result

PV array simulation

The model of the PV module was implemented using a Matlab program. The model parameters are evaluated during execution using the equations listed above in this paper. The program calculates the current *I*, using typical electrical parameter of the module (*Isc*, *Voc*). The characteristics for pv module is simulated using the matlab program.the PV Araay model I shown in fig.

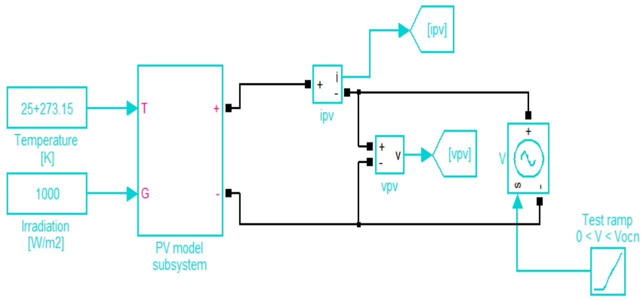

Figure 5.1: PV Array Model

The complete system is depending on the block, use the value of the design variable as the value of a block parameter or may use the variable to compute the value of the block parameter. This PV array model contains two tables. The first table describes the design variables. The second table lists MATLAB functions used to compute computed block parameters during simulation of the system. The system will use equivalent implementation-specific functions to compute the values of computed parameters.

Variables	Value
k (Boltzmann's constant)	1.38e-23
q (charge on an electron)	1.60e-19
A (diode quality)	0.95
Vg (band gap voltage)	1.2
Ns(number of series connected cells (diodes))	36
Temperature	273 + 25
G (number of Sun)1Sun	1000w/m^2

Table I: Parameters of Solar cell in MATLAB Simulink

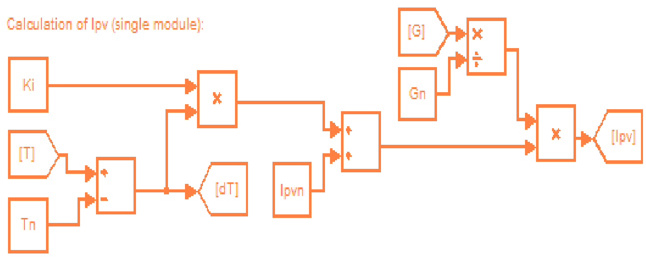

Figure 5.2: Calculation of Ipv (Single Module)

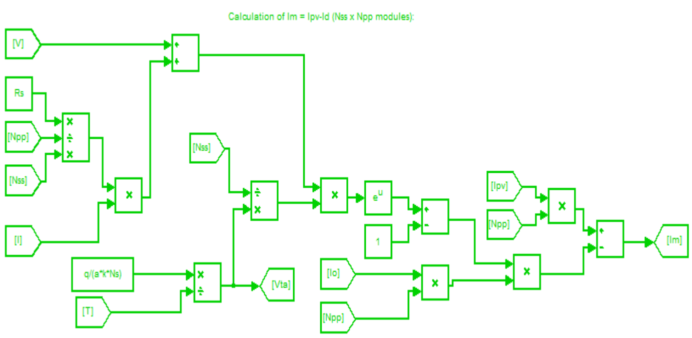

Figure 5.3: Calculation of Im = Id (Nss * Npp modules)

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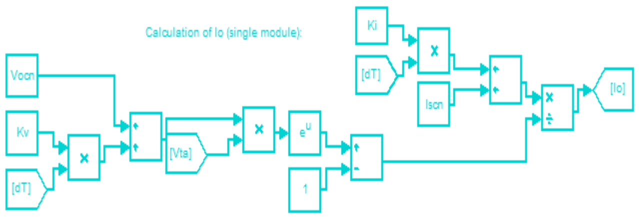

Figure 5.4: Calculation of Io (Single Module)

The advantage of using this high level of implementation is to create a simple equivalent circuit, which have much more complex parameters, including the effect of temperature in the device which is very important for behavior of this type of system. The photovoltaic panel model is validated by simulating at a value of irradiance of 1000 W /m2 and a temperature of 25°C.

The V-I and V-P characteristics of the photovoltaic array is given in Figure 5.5 and Figure 5.6. The V-I curve represent the standard behavior of the photovoltaic cell and photovoltaic array respectively.

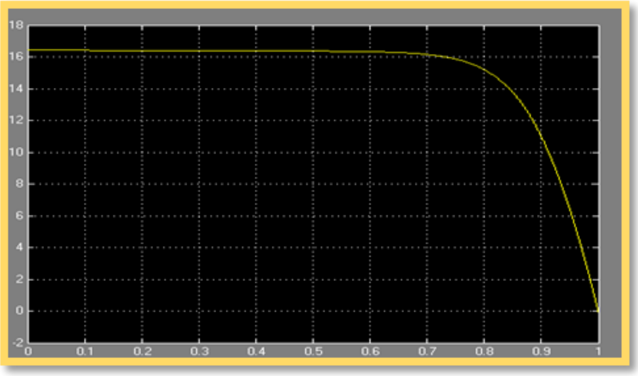

Fig. 5.5: V-I characteristics of photovoltaic array

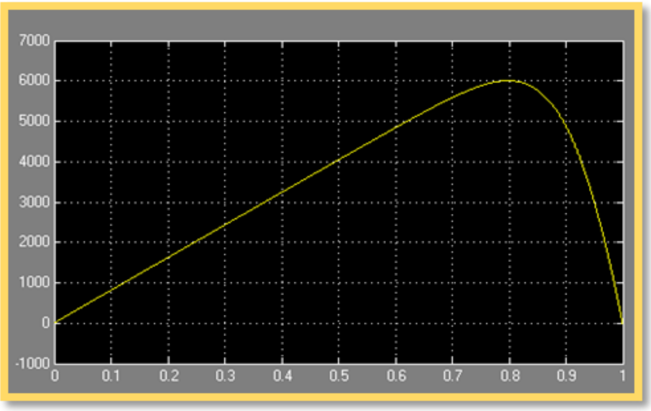

Fig. 5.6: V-P characteristics of the photovoltaic array

Simulation of Solar Energy Using Advance Hill Climb Controller

Now In fig. 5.7, PV array consists of 36 PV modules connected in series altogether generating 17.2 V dc voltage. Basically PV module can be implemented as voltage input type PV module or Current input type PV module. In this paper Current input type PV module is implemented in simulink. The simulink model for single PV module is shown in fig.5.1. PV module parameters are shown in given table I.

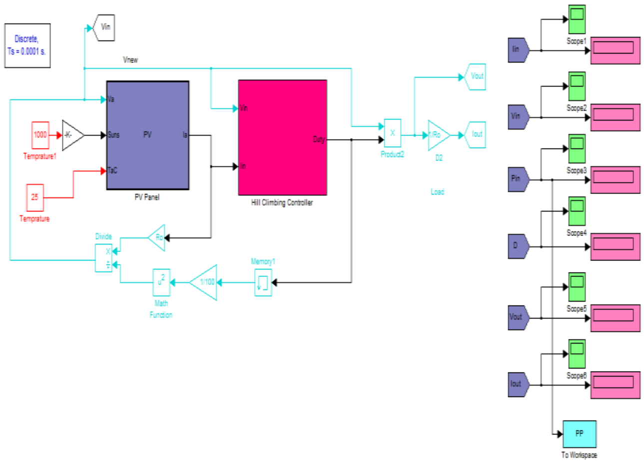

Figure 5.7: PV Array System with Hill Climb Controller

The simulation of the photovoltaic system is made under different conditions of temperature and the irradiation. The modelled has been implemented Hill Climb Controller to maintain the maximal power. The complete system is shown in the Fig. 5.7 and the characteristics of the complete solar module are illustrated in Table II.

Variable	Value
I_{in}	8.809
V_{in}	17.2
P_{in}	156.6
Duty Cycle	66
V_{out}	1136
I_{out}	1419

Table II

At t= 0s to t= 0.04s , the irradiation is at 1000W/m² .the output current become increase from 8.809 to 1419.similary the voltage become 17.2 V to 1136 V which are shown in figure.

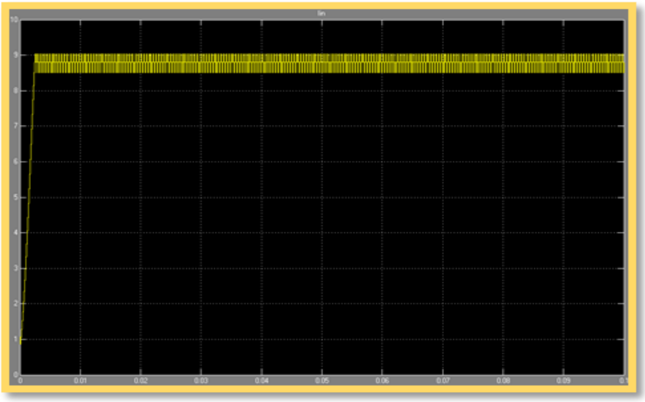

Figure 5.8: Waveform of input Current

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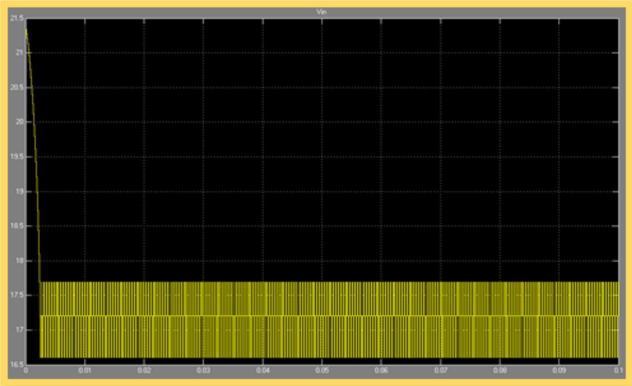

Figure 5.9: Waveform of input Voltage

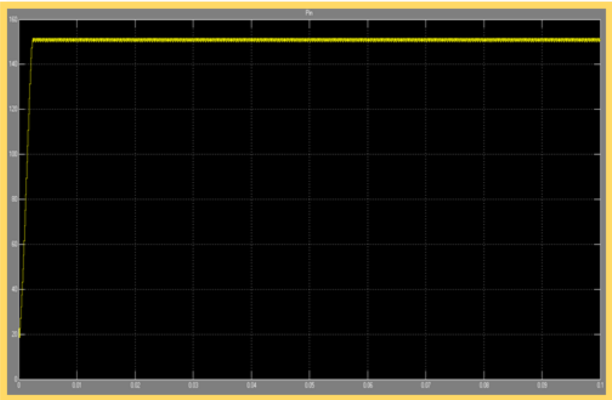

Figure 5.10: Waveform of input Power

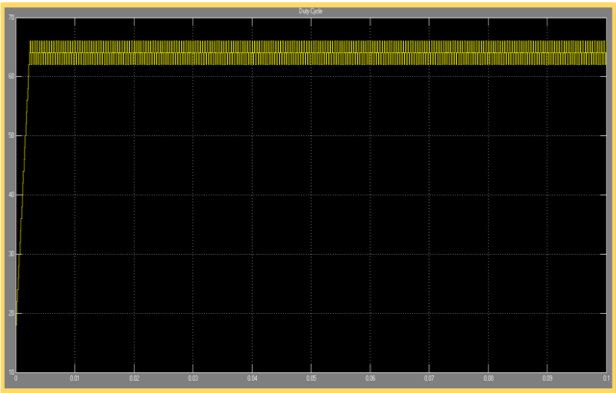

Figure 5.11: Waveform of Duty cycle

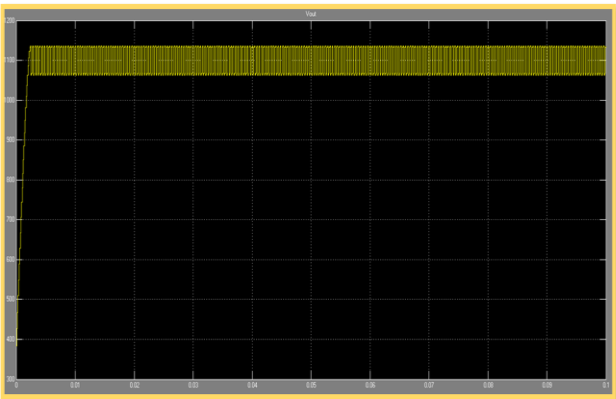

Figure 5.12: Waveform of Output Voltage

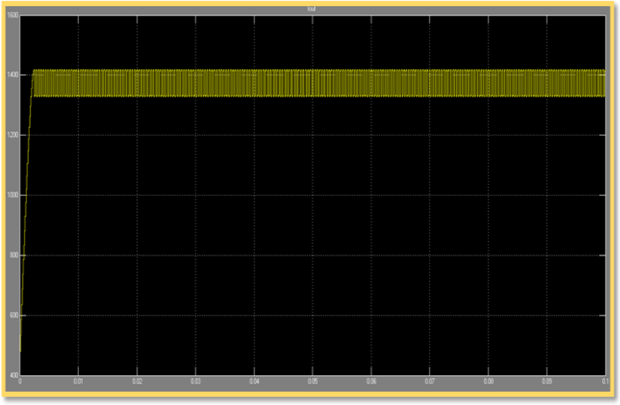

Figure 5.13: Waveform of Output Current

VI. Conclusion

The proposed model is established in SIMULINK software, and output characteristics of photovoltaic array is studied and analyzed. Mainly Advance Hill Climbing Technique is implemented for achieving Maximum Power Point of solar energy. The results shows that both P&O and INC, are more efficient methods than single implementation in system.

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ISSN: 2278 – 7798