



Modelling/Simulation of MPPT Techniques for Photovoltaic Systems Using Matlab

Rohit Kumar¹, Anurag Choudhary², Govind Koundal³, Amritpreet Singh⁴ Akhilendra Yadav⁵

^{1, 2, 3, 4}ME Scholar, ⁵ Assosiate Professor

Electrical Engineering Department

^{1, 2, 3, 4} NITTTTR, Chandigarh, India, ⁵ College of Engineering Roorkee, India

Abstract: This paper deals with simulation/modelling, controlling of maximum power point tracking (MPPT) used in PV systems to maximize the output power of photovoltaic system, irradiation conditions irrespective of the temperature of VI characteristics of load. In this research an important maximum power point tracking technique has been developed, consisting a boost converter, which is controlling pulse given by a microcontroller-based unit. The method used in the proposed PV system for tracking maximum power is perturb & observe algorithm which is directly used to take control action by duty cycle of converter for varying load voltage, thus the complexity of the PV system will be reduced. The result has high-efficiency, lower-cost and can be easily controlled and modified to handle more energy sources. MPPT is a fully electronic system. It varies the electrical operating point of the modules so that they are able to deliver maximum available power.

Keywords: MPPT, Photovoltaic Systems, Simulation, Modelling, control techniques.

I. INTRODUCTION

Solar power is fast growing and one of the most important renewable energy; this hugely increases global energy consumption rate in India [1]. Photovoltaics (PV) system is belonging to research and technology related application of solar cells. The solar energy is the energy converting sun energy with sun light and ultraviolet radiation convert directly into electricity using solar cell [2].

The aim of this research work is to increase the power output and efficiency of the PV system. It is also needing of the constant voltage be supplied to the load irrespective of the variation in solar temperature and irradiance. Parallel and series combination of PV arrays are used to generate electricity depending upon the environmental effects (e.g temperature and solar irradiation) [3].

In solar PV module the efficiency is low [4]. It is necessary to operate on peak power point so that the maximum power can be delivered to the load. The effects of varying temperature and solar irradiation conditions [4]. To increase the efficiency of the system and tracking the maximum power point (MPP) of a photovoltaic (PV) array. The by MPPT techniques is to automatically find the maximum voltage point or maximum current point at which a PV array should obtain the maximum power output under the effects given by temperature and irradiance [5]. The many MPP tracking (MPPT) methods have been developed and implemented. MPPT is a fully electronic system that varies the electrical operating point of the module it capable to deliver maximum available power to the load [6].

II. PHOTOVOLTAICMODELING

In PV modeling, the generation of electrical power is directly converted from sun energy by photovoltaic cell. The panel used in PV modelling works under the photoelectric effect the modeling of photovoltaic system is done by connecting a current source in parallel and inverted diode connected along with a series and a parallel resistance as shown in Fig.1. [7].

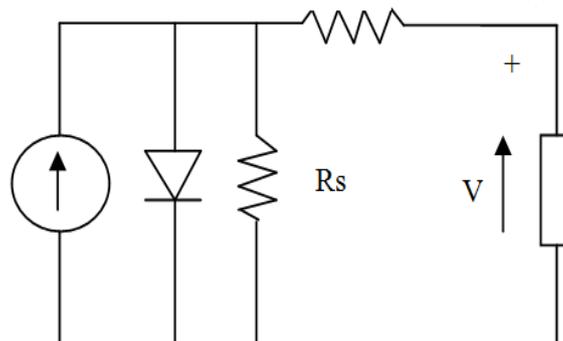


Fig. 1 Single diode model of a PV cell

The mathematical model of Single diode model of a PV cell is expressed by the following equations:

$$I_{ph} = [I_{sc} + K_i(T - 298)] \times \frac{I_r}{1000} \dots\dots (1)$$

Here, Module reverse saturation current I_{rs} ; T : operating temperature (K); I_{sc} : short circuit current (A) ; I_{ph} : photo-current (A); I_r : solar irradiation (W/m²). K_i : short-circuit current of cell at some particular temperature and irradiation.

$$I_{RS} = I_{sc} [\exp(qV_{OC}/N_s k_n T) - 1] \quad (2)$$

Here, k : Boltzmann's constant, = 1.3805×10^{-23} J/K. V_{oc} : open circuit voltage (V); q : electron charge, = 1.6×10^{-19} C; n : the ideality factor of the diode; N_s : number of cells connected in series.

When the temperature varies, the saturation current I_0 of the module is also varies :

$$I_0 = I_{RS} \left[\frac{T}{T_r} \right]^3 \exp \left[\frac{q \times E_{g0}}{nk} \left(\frac{1}{T} - \frac{1}{T_r} \right) \right] \quad (3)$$

Here, E_{g0} : band gap energy of (semiconductor used in PV system) = 1.1 eV; T : nominal temperature = 298.15 K;

The output current of panel calculation:-

$$I = (N_p \times I_{ph} - N_p \times I_0) \times \left[\exp \left(\frac{\frac{V}{N_s} + I \times \frac{R_s}{N_p}}{n \times V_t} \right) - 1 \right] \quad (4)$$

With

$$V_t = \frac{k \times T}{q} \quad (5)$$

And

$$I_{sh} = \frac{(V \times \frac{N_p}{N_s}) + (I \times R_s)}{R_{sh}} \quad (6)$$

Here: R_s : series resistance (Ω); V_t : diode thermal voltage (V) N_p : No. of solar panel are connected together in parallel ; R_{sh} : shunt resistance (Ω); [8].

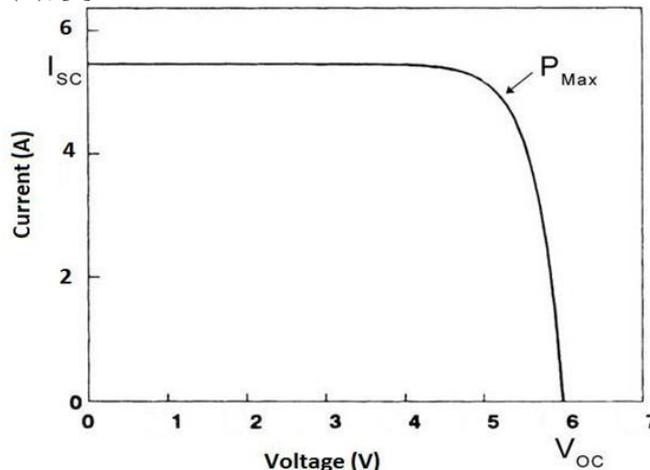


Fig.2:- I-V characteristics of PV model

In the solar panel model to performing better result, by using two diode models but in proposed work our aims of this study focus on the single diode model. [9].

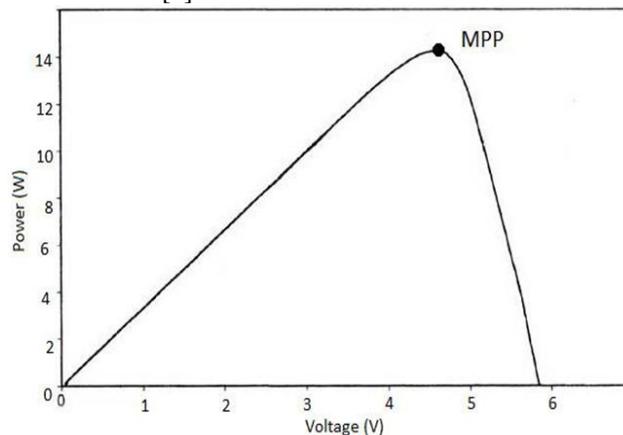


Fig.3: P-V characteristics curve of photovoltaic cell

The power voltage characteristics of the PV system are found by the multiplication of voltage and current as shown in Fig 3. The maximum power will be achieved, depend on the amplitude of voltage and current, the point denoted by MPP in Fig. 3.

III. BOOST CONVERTER

Basically, dc-dc boost converter is mostly used in nowadays for many industrial applications, which a variable dc supply needed. In solar application dc-dc boost converter use for boosting the output voltage of solar panel for varying in the input side resistance of solar panel compare with the load side resistance by changing the duty cycle a boost converter [11]. A boost converter is use for this work, it misses out the maximum tracking point, our system either for trying to other application such as water pumping system which operate on 230 V, so we use a boost converter [12].

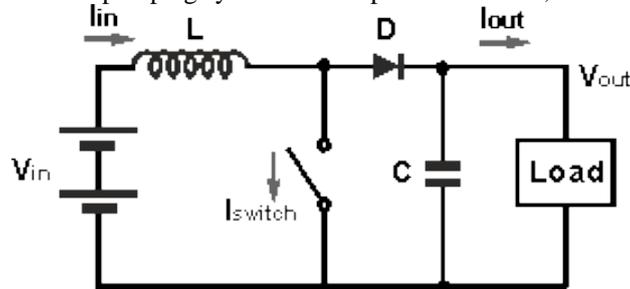


Fig.4. Boost converter circuit

Mode 1-The operating condition of the boost converter is depending on the duty cycle of the switching frequency, if the switch is closed (ON), battery provides the charging current to the inductor and inductor is fully charged. There is no current flowing through the diode cause of capacitor polarity and so that load current remains constant which is being supplied due to the discharging of the capacitor [13].

Mode 2- In the operation of second mode the switch is disconnecting (off), the diode is becomes forward bias. The capacitor will charged through the energy released by inductor. The load current remains constant in the operation of boost converter [13].

IV. MAXIMUM POWER POINT TRACKING

The many techniques are available for achieving the maximum power from solar PV system.

Some important techniques are given below:

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

The algorithm will be depends on the complexity of circuit and time takes to track the maximum power point, in this model, perturb & observe algorithm implemented using MATLAB/Simulink [14].

A. Perturb & Observe

The simplest method of MPPT technique is Perturb & Observe (P&O). This model is developed by using only one sensor (voltage sensor) which connected to output voltage of PV panel to sense the panel voltage, hence the model easy to implement in MATLAB/Simulink. This algorithm has less time consuming to achieve maximum power point. [15].

However the strategy does not asses the rapid change of irradiation level (because of changing maximum power point) it considers disadvantage of p & o algorithm as a change in maximum power point due to perturbation and winds up computing the wrong maximum power point. This limitation can be overcome by use incremental conductance method to avoid this problem [16].

B. Incremental Conductance

In the method of Incremental conductance, we need two current sensors for output current sensing purpose and two voltages sensor for sensing output voltage of the PV array [17].

The slope of the PV curve is 0 at maximum power point.

$$\left(\frac{dP}{dV}\right)_{MPP} = d(VI)dV \quad (7)$$

$$0 = I + \frac{VdI}{dV} \text{ MPP} \quad (8)$$

$$\left(\frac{dI}{dV}\right)_{MPP} = -\frac{I}{V} \quad (9)$$

In this method first sensing the current and voltage simultaneously by sensor used in circuit. However the cost of implementation and complexity of the method will increase periodically [18].

This is the cause of widely used both Perturb & Observe and Incremental Conductance method algorithms. In this work, we have selected P & O algorithm for simplicity our study [19].

C. Fractional Open Circuit Voltage

In this section, the maximum power point tracking is estimated by using the models of the PV generator are discussed by similar method. The linear relationship between V_{MPP} (voltage at maximum power point) and V_{OC} (open circuit voltage) of the Photovoltaic system, with variation in irradiance levels and temperature, by following equation of fractional V_{OC} method.

$$V_{MPP} = k1 V_{oc} \quad (10)$$

In equation k1 is known as constant of proportionality, its depends on the characteristics of the Photovoltaic system being used. The factor k1 has been range to be between 0.71 and 0.78. at these value of k1 is known, the voltage at maximum power point V_{MPP} can be calculated by periodical measurement of open circuit voltage V_{oc} by momentarily shutting down the power converter of the system [20].

D. Fractional Short Circuit Current

In this section fractional I_{sc} results, with variations of atmospheric conditions, as current at maximum power point I_{MPP} has linearly increase and related to the I_{sc} short circuit current of the PV system. The relation between both currents is;

$$I_{MPP} = k2 I_{sc} \quad (10)$$

In equation k2 known as constant of proportionality. The fractional open circuit voltage method, k2 compute by the photovoltaic system. The range of k2 constant of proportionality is between 0.78 and 0.92. The short circuit current measuring I_{sc} during operation is problematic condition. As a result seen an additional switch added to the power converter to periodically short the PV system, so that current sensor is used to measure I_{sc} [21].

E. Fuzzy Logic Control

Fuzzy logic controller is widely used in machine control application in industry [22].The controller output in form of linguistic labels represented by fuzzy sets has to be converted into a crisp solution variable before it can be used to control the system. The fuzzy input variables for fuzzy logic based MPPT algorithms developed the characteristics of PV system. The researchers are going on fuzzy MPPT controller designs with the designs will be verified by MATLAB/Simulink on computer. [23].

F. Neural Network

A neuron is a cell which made by a cellular body and ramifies to form the dendrites [24]. Dendrites transfer the information between the body of the neuron and soma, Synapse is the junction between two neurons, and its work as a controlling valve to control the rate of flow of information. The technique of implementing MPPT well for microcontrollers based application. The neural networks divide into three layers: input, output and hidden layers. The layer has numbers of nodes which totally depend on user and their input variables like V_{oc} (open circuit voltage) and I_{sc} (short circuit current) with environmental data like temperature and irradiance [25].

Table 1:- Different MPPT techniques with their Characteristics

Techniques used for MPPT	Characteristics			
	Implementation Complexity	Periodic Tuning	Convergence Speed	Sensed parameters
Neural network	High	Yes	Fast	Varies
Fuzzy logic control	High	Yes	Fast	Varies
Perturb & observe	Low	No	Varies	Voltage
Fractional V_{oc}	Low	Yes	Medium	Voltage
Fractional I_{sc}	Medium	Yes	Medium	Current
Incremental Conductance	Medium	No	Varies	Voltage, current

V. PERTURB & OBSERVE ALGORITHM

In Perturb and Observe algorithm technique, small increment are occur in operating voltage, when PV system is perturbed coming result varies with the power of panel is positive, then we are going for the tracking techniques of maximum power point by perturbing in the maximum power in the same direction. If the coming result is negative, then the direction of maximum power point changed its perturbation sign of the PV system [26]

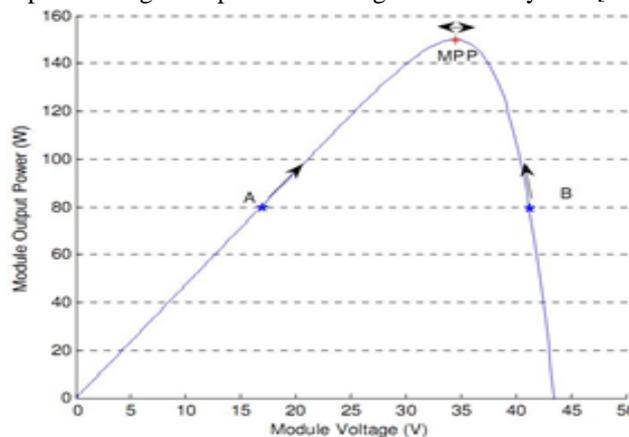


Fig.5:- Solar panel characteristics showing MPP and operating points

In the Fig.5 shows the plot of module output power versus module voltage in solar panel at a given irradiation. The Maximum Power Point, point marked as MPP is the theoretical maximum output power obtainable from the PV panel. It has two operating point 'A' and 'B'. The maximum power point gives a positive perturbation to the system voltage and point B like on the right hand side of the maximum power point. In positive perturbation, magnitude of power goes in negative direction, thus perturbation it is change the direction of to tracking the maximum power point Fig.6.shows P&O algorithm flowchart. [27].

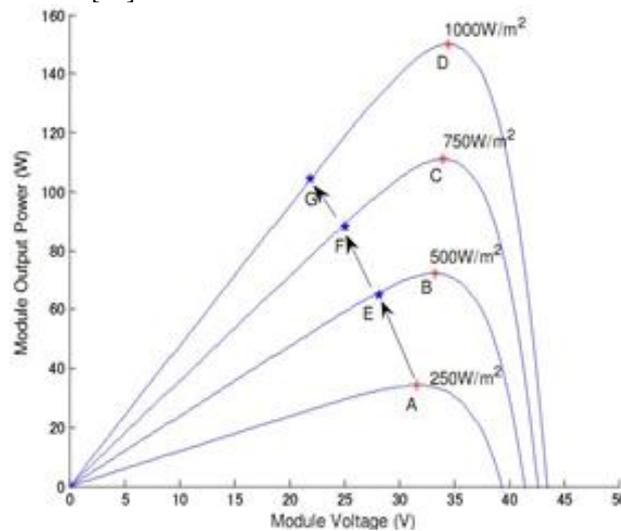


Fig. 6:- PV curve depending on irradiation

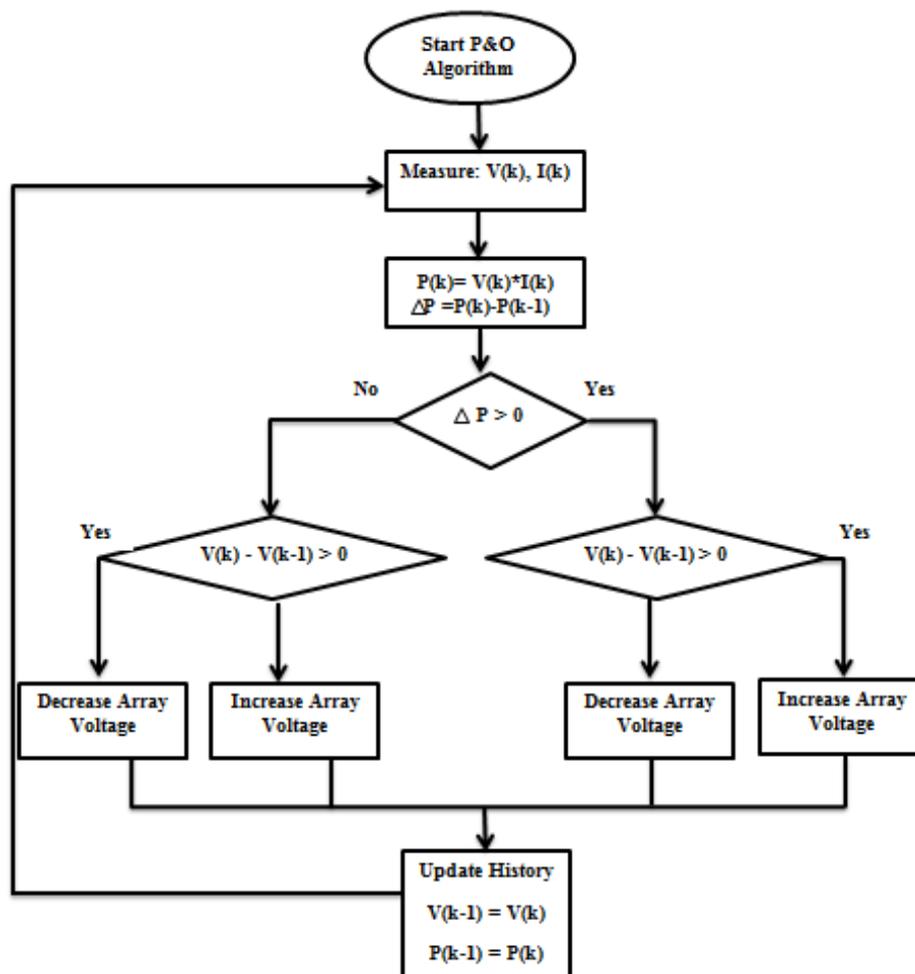


Fig. 7:- Perturb & Observe algorithm flowchart

The effects of irradiation on the output voltage of the PV system, when the irradiance changes rapidly Fig.7 shows the curve points 'AEFG' shows wrong tracking of the maximum power and also moving in the unlike side of the curve, it takes a change due to change in perturbation. The next step will take by changes the iteration; the perturbation direction will be change and hence goes away from the maximum power point [28].

The only voltage sensor is used in this algorithm to sense the voltage of PV array. The algorithm has tracking the maximum power point with respect to other methods for an appropriate error limit or increasing the time complexity of the algorithm [29].

VI. MODELING OF PHOTOVOLTAIC SYSTEM

In this section the architecture of photovoltaic system is shown in Fig.7. A single phase inverter and boost converter using modelling. The panel output is given to the boost converter after boosting the voltage is connected to invert and then supply to load. In this MPPT algorithm switching pulse generated and given to the boost converter for varying the duty cycle of the boost converter. The interfacing with renewable energy sources is also possible for different solar panels can be feed to the inverter as a dc source [8]. The power coming from battery backup is given to inverter through a bi-directional dc-dc converter; the controlled flow of electrical power in either direction is possible by varying duty cycle.

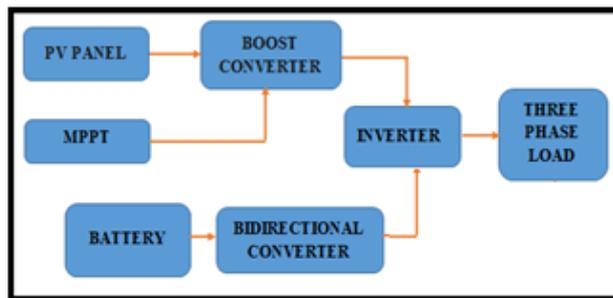


Fig.8 Block Diagram of MPPT Techniques based Photovoltaic System

A. Maximum Power Point Tracking

In this modeling we develop perturb and observe algorithm to be adopted for considering its simplicity compare than other techniques. For implementation of Maximum power point tracking techniques (MPPT) is use to achieve the maximum power from Photovoltaic system. The Simulink model shows in Fig.9

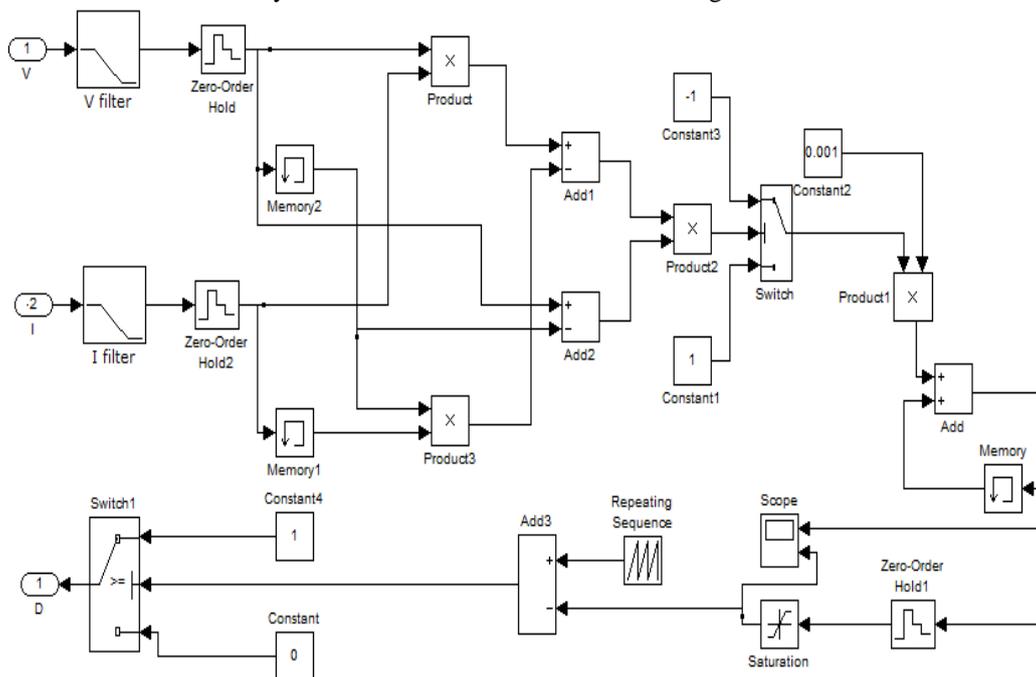


Fig. 9:-Simulink model of MPPT

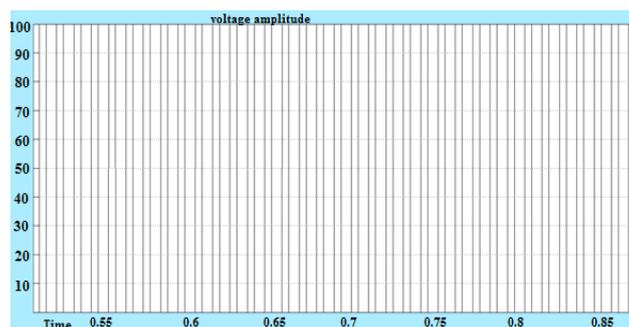


Fig.10:- The output waveform of MPPT

B. DC-DC Converter

The In this section solar panel is connected with Inverter through a boost converter. Maximum power point tracking algorithm is provide pulse to boost converter to obtaining output voltage $V_o = D V_d$ where V_d is the input voltage and D is the duty ratio of the converter. The output of the boost converter is given as the input to the single phase inverter connected with load.

C. Bi-Directional Converter

In this section, simulink model of a bidirectional dc-dc converter is shown in Fig.11; the dc-dc bidirectional converter is to maintain the constant voltage of dc link [29]. Switch Sw1 works as charging switch, Sw1 is on and converter works as a boost converter and boosting the voltage. When discharging, switch Sw2 is on and converter works as a buck converter and step down the voltage.

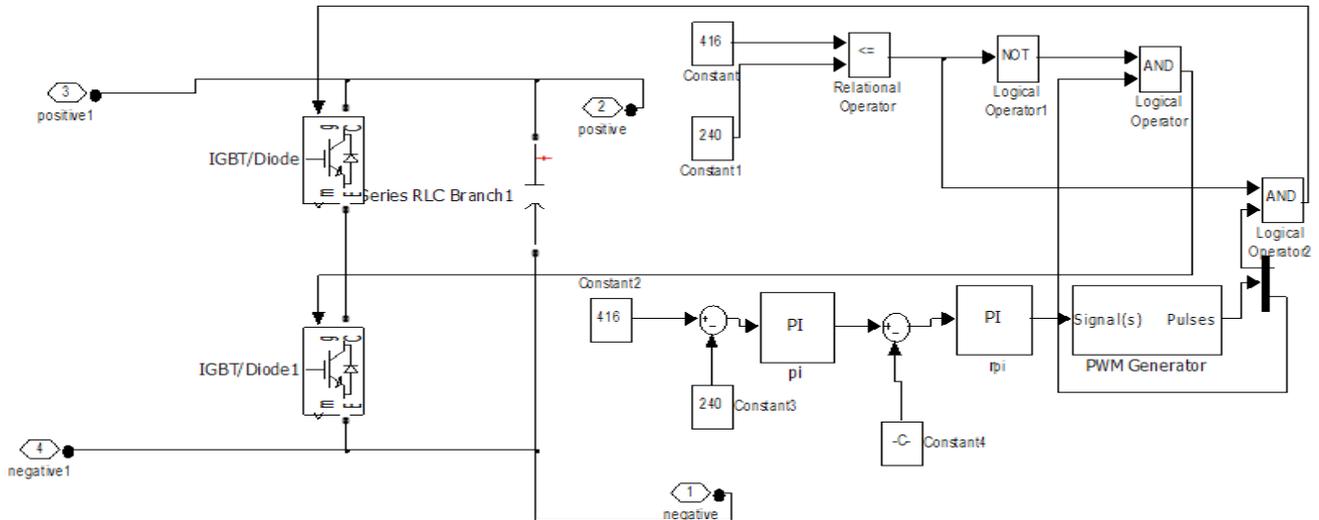


Fig. 11:-Bidirectional dc-dc converter

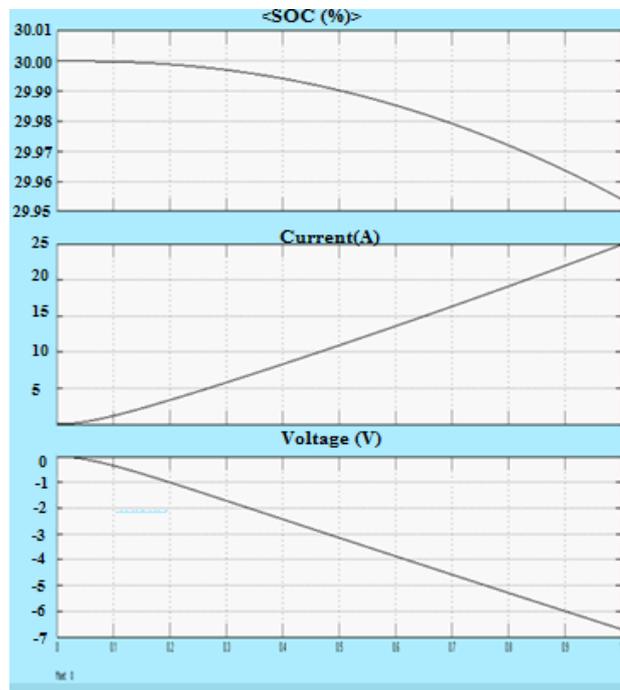


Fig.12:- Output Waveform of Battery

In the result shows Fig. 12, this control scheme is used for the controlling of dc-dc bidirectional converter. The reference voltage is more than the dc link voltage, switch Sw2 is closed (ON position). When the voltage of dc link is greater than the reference voltage, switch Sw1 is closed (ON position).

D. Inverter

It is IGBT use as switch connected with an uncontrolled diode in anti-parallel manner. IGBT is able to current conducting in both directions. In which switches junction point in one leg of inverter represent output point for the connected load to the system [30]. In simulation of half bridge inverter, load connected to mid-point of the input dc

source and juncture point of the both switches of inverter shows in Fig. 13. If assumed that input side voltage of inverter is constant and both switches have no loss. The concept of half bridge, input voltage is divided in two equally parts with help of a loss free capacitive potential divider. The electronics switch is connected to Each legs of inverter within dotted lines in the Fig.13 Sw1, Sw2 on then output voltage will be $+V_s$ and when Sw3 and Sw4 are on output voltage will be $-V_s$.

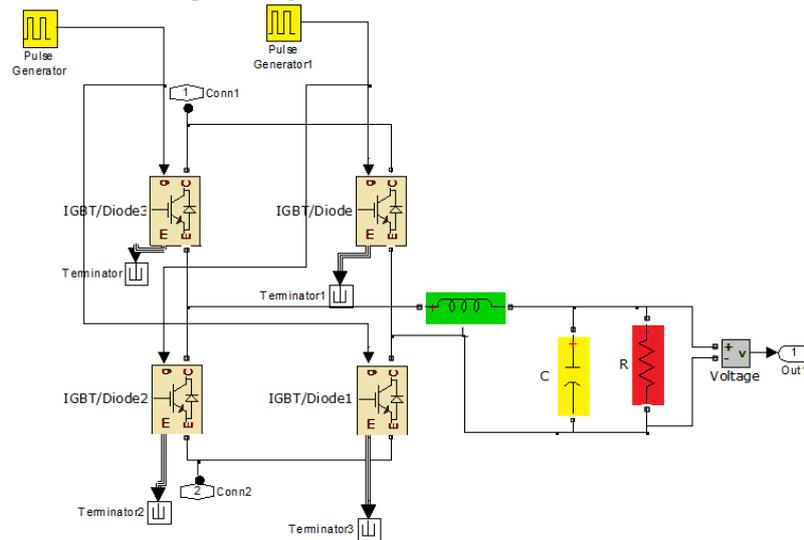


Fig 13:-Simulink of Single Phase Inverter

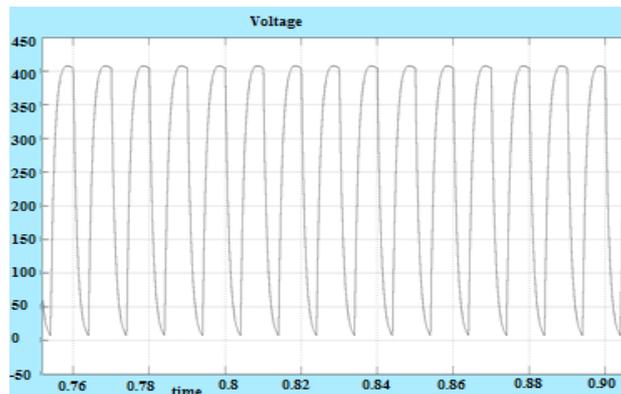


Fig 14:- output waveform of inverter

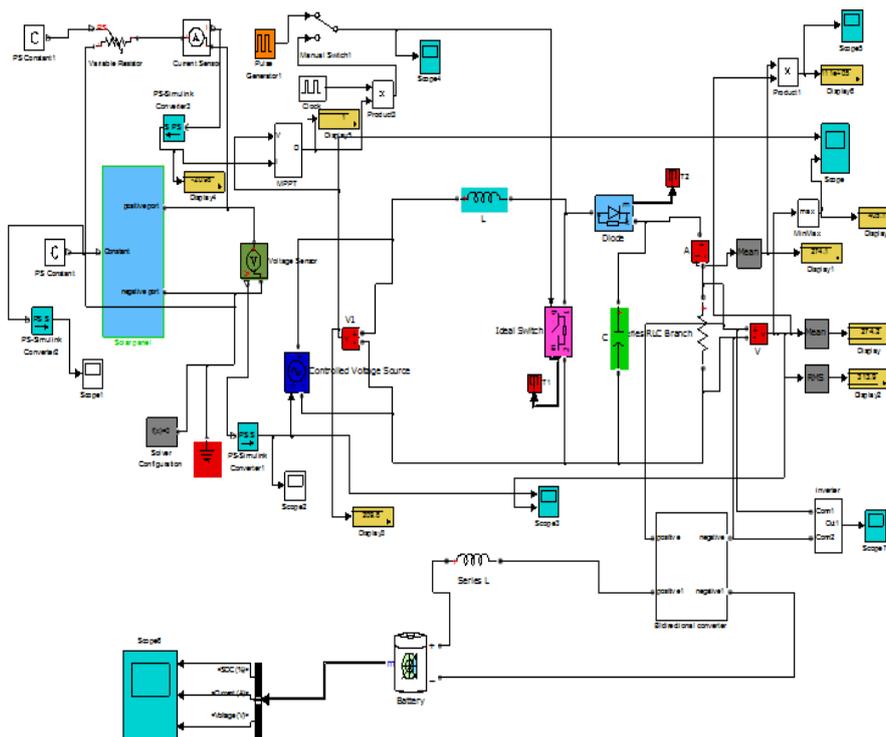


Fig.15:- complete Simulink of MPPT Techniques based photovoltaic system

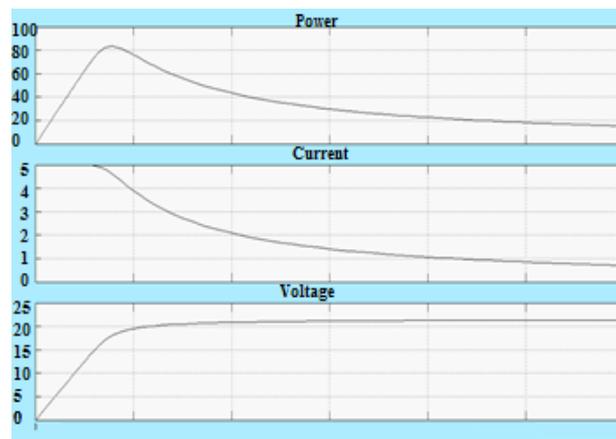


Fig16.wave form representation of the solar panel

In the result, three subsystems are used in this model. First subsystem is PV module and other subsystems model used of I_{ph} and I_{rs} .

VII. CONCLUSION

This paper covers one of the most important requirements of PV system, tracking of maximum power point in system. In the simulation model with p & o algorithm technique was first run by using a switch without tracking technique mode. Another one with perturb & observe algorithm MPPT technique, if comparing in the result the power obtained from the solar panel with 95 Watts and solar irradiation available 85 Watts per sq. cm. It's useful to small load, less than 95 Watts connected with panel. The result coming with perturbs & observes algorithm MPPT technique (PI controller) is feeding the reference voltage and compute by the P&O method. In the similar irradiation level, panel generates 250 Watts power without load. The conversion efficiency came out to be increase with using MPPT technique. 215 Watts power obtained at the load side, the efficiency of the photovoltaic system increase. The switching losses power available at 250 Watts provides by the PV system can be reducing by high frequency PWM switching circuit. Therefore, the result shows those P & O algorithm technique for maximum power tracking improve the efficiency of the Photovoltaic system by around 120%. In the first case power available of earlier output is around 95 Watts. After using the MPPT techniques output increase around 215 Watts.

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