Analysis and Simulation Of Perturb and Observe Mppt Technique

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Abstract

As **the energy demand and the environmental problems increase, the natural energy sources have become very important as an alternative to the conventional energy sources. Due to the capability of PV cells converting light directly to electricity has stimulated new research areas on PV cells so that the PV array applications have emerged as a solution to the growing energy crisis since mid 1970s. Although the solar cell prices are very expensive at the beginning, they have become cheaper during last decade due to developing manufacturing processes [I], so that it is expected that the electricity from PV arrays will be able to compete with the conventional ones by the next decade [2]. PV array systems should be designed to operate at their maximum output power levels for any temperature and solar irradiation level at all the time.**

Maximum Power Point Tracking (MPPT) algorithms are employed in photovoltaic (PV) generation systems to make full utilization of PV array output power which varies with external environment and loads. Several techniques have been proposed for maximum power tracking. Among them Open circuit (OC), Short circuit (SC) and Perturb & Observe (P & O) MPPT are mostly used in PV system. The OC and SC methods are simple but do not accurately the maximum power. In order to overcome the above drawback P&O method is used. The method operates by periodically changing the output voltage of the solar array and evaluating the corresponding output power. When the maximum of the product I*V is found, the MPP has been located. The simulation model makes use of basic circuit equations of PV solar cell based on its behavior as diode and comprehensive behavioral study is performed under varying conditions of solar isolation, temperature, varying diode model parameters, series and shunt resistance etc. The simulation and experimental results show that the proposed MPPT control can avoid tracking deviation and result in improved performance in both dynamic and steady-states.

Keywords: MPPT (Maximum Power Point Tracker), P&O (Perturb and Observe), PV (Photovoltaic), Photovoltaic system, Boost Converter.

I. INTRODUCTION

The use of new efficient photovoltaic solar cells (PVSCs) has emerged as an alternative measure of renewable green power, energy conservation and demand side management. The rapid trend of industrialization of nations and increased interest in environmental issues recently led us to explore the use of renewable forms such as solar energy. Although the efficiency of PV panels is currently still poor and its use is small. Solar photovoltaic (PV) power has a particularly promising future. The global PV market has experienced vibrant growth for more than a decade (since 2000) with an average annual growth rate of 40% and it has significant potential for long-term growth over the next decades. The cumulative installed PV power capacity has grown from 0.1 GW in 1992 to 14 GW in 2008. Annual worldwide installed new capacity increased to almost 6 GW in 2008 [3]. PVs use special semiconductor materials to utilize the solar energy by converting it to an electrical energy. Doping two different semiconductor materials by different imputes forms two types of semiconductor layers that are used to fabricate solar cells. This connection is called (p-n junction), which is the basic building block of the PV system. This semiconductor is the material that can conduct electricity when the temperature raises or when exposed to light. Solar cell or PVs cell directly convert the solar energy into electricity by the photovoltaic effect. This phenomenon is similar to the photosynthesis in the plant that converts the sunlight into bio-energy. The mono crystalline and polycrystalline silicon cells are the only found at commercial scale at the present time. Silicon PV cells are composed of a thin layer of bulk Si or a thin Si film connected to electric terminals. One of the sides of the Si layer is doped to form the p–n junction. A thin metallic grid is placed on the sun-facing surface of the semiconductor. This paper focuses on modeling photovoltaic modules or panels composed of several basic cells. In order to implement the cell into real application, a combination of cells forms different sizes where a module consists of connected PV cells in one frame, and an array is a complete PV unit consisting of connected modules with structural support [4]. Each PV array is comprised of parallel connected strings. Each string consists of multiple series connection of PV modules that provide the required voltage of the array. These structures can be used to supply power to scalable applications known as photovoltaic plants which may be stand-alone systems or grid-connected systems.

The performance of a PV array system depends on the operating conditions as well as the solar cell and array design quality. The output voltage, current and power of a PV array vary as functions of solar irradiation level, temperature and load current. Therefore the effects of these three quantities must be considered in the design of PV arrays so that any change in temperature and solar irradiation levels should not adversely affect the PV array output power to the load or utility, which is either a power company utility grid or any standalone electrical type load. To overcome the desired effects of the variable temperature and solar irradiation on the output power of PV systems, two control strategies have usually been applied: 1). Controlling the san input to the PV array, and 2). Controlling the power output from the PV array. The combinations of these two groups may also be considered. Both groups may include electrical or thermal energy storage systems or auxiliary power sources which supply electricity during the nights and cloudy days. Sun input to the PV systems is kept as high as possible either by rearranging the solar cell configurations of PV arrays with respect to the changes in weather conditions or by designing and controlling the position of sun tracking solar collectors. Owing to changes in the solar radiation energy and the cell operating temperature, the output power of a solar array is not constant at all times. Consequently, during the design process a simulation must be performed for system analysis and parameter settings.

II. HOW A PV CELL WORKS

Solar cell consists of a p-n junction fabricated in a thin wafer or layer of a semiconductor material. Photovoltaic cells are made of several types of semiconductors using different manufacturing processes. . The commercial solar cell is made of wafer-based technology of semiconductor materials, such as Crystalline Si (C-Si) and thin film. Different types of silicon can be used to fabricate the solar cell i.e. mono-crystalline silicon, poly-crystalline silicon, and amorphous. The variation between these types is distinguished by the conversion efficiency of the PV cell. Fig. 1 roughly illustrates the

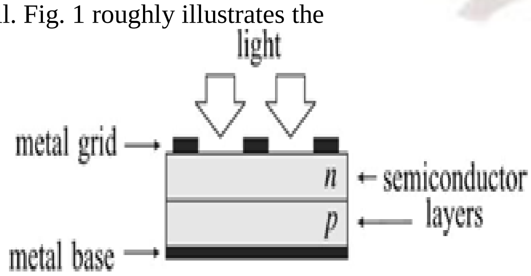

Fig.1.Stucture of a PV cell

physical structure of a PV cell. . When photons from the solar energy hits the solar cell, with energy greater than band gap energy of the semiconductor, electrons are knocked loose from the atoms in the material, creating electron-hole pairs. These carriers are swept apart under the influence of the internal electric fields of the p-n junction and create a current proportional to the incident radiation. When the cell is short circuited, this current flows in the external circuit; when open circuited, this current is shunted internally by the intrinsic p-n junction diode. The rate of generation of electric carriers depends on the flux of incident light and the capacity of absorption of the semiconductor. The capacity of absorption depends mainly on the semiconductor band gap, on the reflectance of the cell surface (that depends on the shape and treatment of the surface), on the intrinsic concentration of carriers of the semiconductor, on the electronic mobility. The solar radiation is composed of photons of different energies. Photons with energies lower than the band gap of the PV cell are useless and generate no voltage or electric current. Photons with energy superior to the band gap generate electricity, but only the energy corresponding to the band gap is used—the remainder of energy is dissipated as heat in the body of the PV cell. Semiconductors with lower band gaps may take advantage or a larger radiation spectrum, but the generated voltages are lower.

III. MODELLING OF PV ARRAY

PV arrays are built up with combined series or parallel combinations of PV solar cells, which are usually represented by a simplified equivalent circuit model such as the one given in Fig. 2 and/or by an equation as in (1). A photovoltaic cell is basically a semi-conductor diode whose p–n junction is exposed to light [5], [6]. Modeling is basic tool of the real system simulation. For modeling, it is necessary to analyze the influence of different factors on the photovoltaic cells. The mathematical models for photovoltaic cells are based on the theoretical equations that describe the operation of the photovoltaic cells and can be developed using the equivalent circuit of the photovoltaic cells. The most common one is as follows.

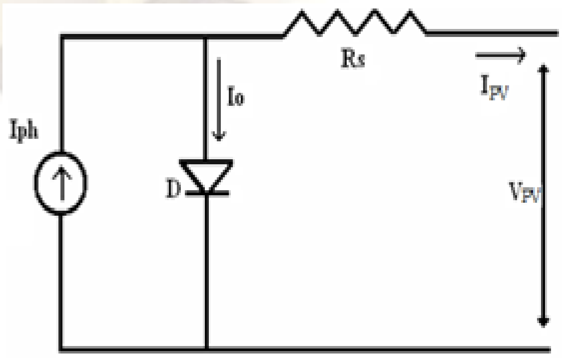

Fig.2. Equivalent circuit of PV cell

Solar cell generated current depends on the characteristic of material, age of solar cell, irradiation and cell temperature. A double exponential equation may be used for the polycrystalline silicon cells.

$$I = I_{ph} - I_s\left(\frac{exp(q.(V+IRs))}{N.K.T} - I\right) - \frac{(V+IRs)}{Rsh} \quad (1)$$

Equation (2) represents output voltage of a PV cell

$$Vpv = \left[\frac{NsAKT}{q}\right] ln\left[\frac{Np\times Iph - Ipv + Np\times Io}{Io}\right] - IpvRs \quad (2)$$

Output current of a PV cell

$$Ipv = Np\times Iph - Np\times Io\left[exp\left\{\frac{q\times(Vpv+IpvRs)}{NsAKT}\right\} - 1\right] \quad (3)$$

Where,

$$Iph = [Iscr + Kt(T-298)]\times\frac{\lambda}{100} \quad (4)$$

$$Io = Ior\left[\frac{T}{Tr}\right] exp\left[\frac{q\times Ego}{BK}\left\{\frac{1}{Tr}-\frac{1}{T}\right\}\right] \quad (5)$$

The PV array power can be calculated using the following equation

$$Ppv = Vpv\times Ipv \quad (6)$$

$$Ppv = Vpv\times Np\times Iph - Vpv\times Np\times Io\left[Exp\left\{\frac{q\times(Vpv+IpvRs)}{NsAKT}\right\} - 1\right] \quad (7)$$

Where,

Vpv is output voltage of a PV cell (V)
Ipv is output current of a PV cell (A)
Ns is the number of modules connected in series
Np is the number of modules connected in parallel
Iph is the light generated current in a PV cell (A)
Io is the PV cell saturation current (A)
Rs is the series resistance of a PV cell (Ω)
A=B is an ideality factor =1.6
K is Boltzmann constant =1.3805e-23Nm/K
T is the cell temperature in Kelvin =298K
Q is electron charge =1.6e-19 Coulombs
Tr is the reference temperature =301.18K
$Iscr$ is the PV cell short circuit current
N = No of cells
Rsh is shunt resistance of a PV cell
$\boldsymbol{\lambda}$ is the PV cell illumination (MW/cm^2)
Ior is the saturation current at T_r
E_{go} is the energy band gap (ev)

Both k and T should have the same temperature unit, either Kelvin or Celsius. The curve fitting factor A is used to adjust the I-V characteristics of the cell obtained from the actual characteristics obtained by testing. Eq. (2) gives the voltage of a single solar cell which is then multiplied by the number of the cells connected in series to calculate the full array voltage. Since the array current is the sum of the currents flowing through the cells in parallel branches, the cell current IC is obtained by dividing the array current by the number of the cells connected in parallel before being used in (1), which is only valid for a certain cell operating temperature T with its corresponding solar irradiation level Sc. If the temperature and solar irradiation levels change, the voltage and current outputs of the PV array will follow this change. Hence, the effects of the changes in temperature and solar irradiation levels should also be included in the final PV array model. The complete behavior of PV cells are described by five model parameters (I_{ph}, N, Is, Rs, R_{sh}) which is representative of the physical behavior of PV cell/module. These five parameters of PV cell/module are in fact related to two environmental conditions of solar isolation & temperature. The determination of these model parameters is not straightforward owing to non-linear nature of equation.

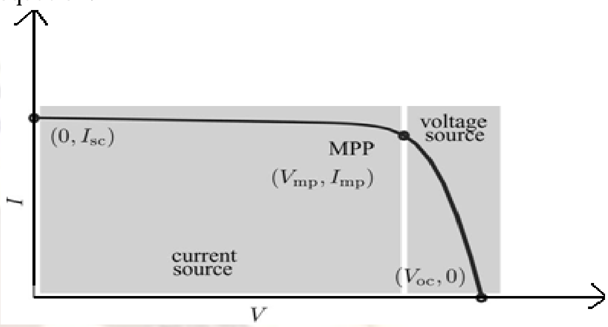

Fig.3. Maximum Power Point (V_{mp}, I_{mp})

Characteristic I–V curve of a practical PV device and the three remarkable points: short circuit (0, I_{sc}) , MPP (V_{mp}, I_{mp}), and open circuit (V_{oc} , 0). The short circuit current slightly increases with cell temperature. For practical use, PV cells can be ampere curve electrical connected in different ways: series or parallel. Figure 4 and Figure 5 present how the volt is modified in the cases when two identical cells are connected in series and in parallel. PV cells are first connected in series in most manufacturing methods to form PV module. Modules can be connected in different ways to form PV array. This is done for the sake of voltage/current requirement of the power conditioning units (PCU's) of the PV system. In order to do that, a series and parallel connections of PV modules are needed. It is seen that volt ampere characteristics of series interconnected cells can be found by adding, for each current, the different voltages of the individual cells. On the other hand, for parallel cells the currents of the individual cells must be added at each voltage in order to find the overall volt-ampere curve.

(A) Simulation model of PV cell Based on Matlab / Simulink

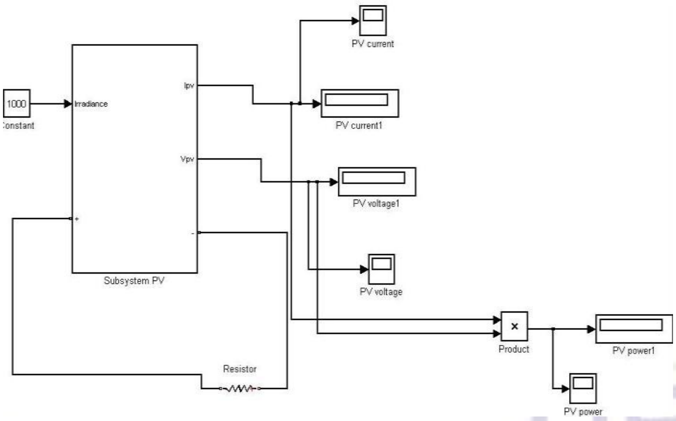

Fig.6. Simulation model of PV cell

The output characteristic of a photovoltaic (PV) array is nonlinear and is influenced by solar irradiance level, ambient temperature, wind speed, humidity, pressure, etc. The irradiation and ambient temperature is two primary factors. To study the output characteristics of PV cell, some experiments based on simulation of PV cell have been done.
For constant temperature (25˚C) and different intensity (40-100mW/cm2) The PV array current constant up to some voltage level (100V) and then it will be decreased. The PV array current always increases with intensity.

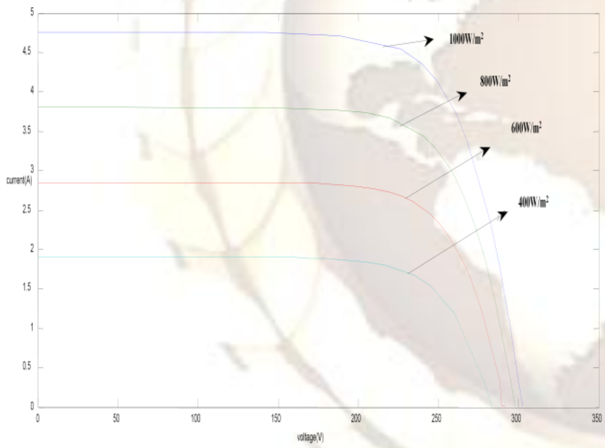

Fig7(a). I-V characteristics of Solar array for various irradiance at a constant temperature of 25^{0}C .

For constant temperature (25˚C) and different intensity (40-100mW/cm2) The PV array power increases up to some voltage level (100V) and then it will be decreased. The PV array power always increases with low to high intensity.

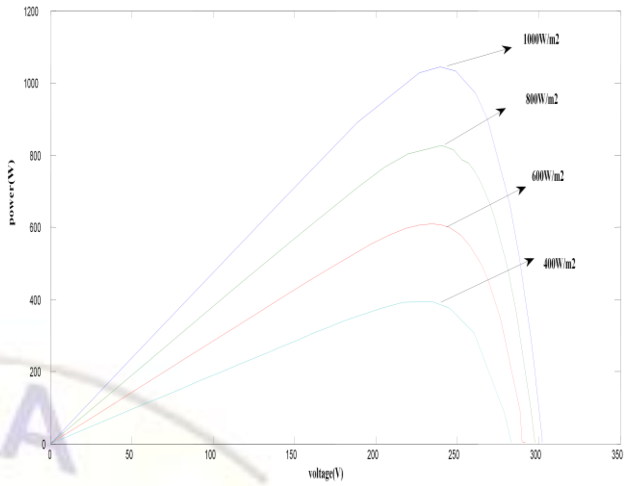

Fig 7(b). P-V characteristics of Sola array for various irradiance at a constant temperature of 25^{0}C.

From figure.8 (a) P-V characteristics for different temperature and constant irradiance the generated power is gradually decreased and maximum power available more at low temperature.
From figure.8 (b) I-V characteristics for different temperature and constant irradiance the current is constant up to some voltage and then it will decrease gradually.

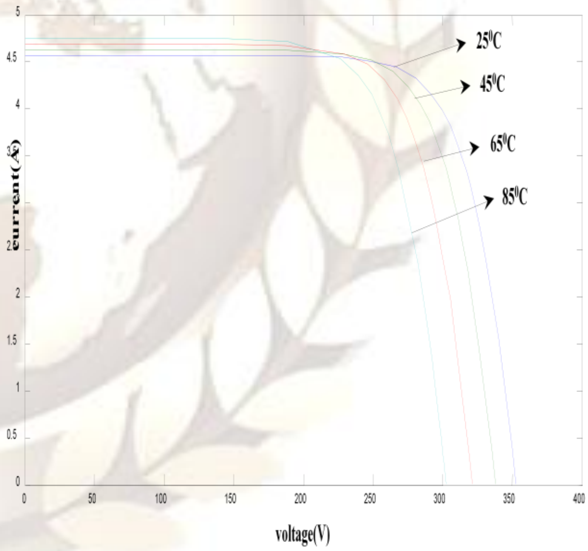

Fig8(a). I-V characteristics of Solar array for various temperature at constant irradiance of 1000W/m^2.

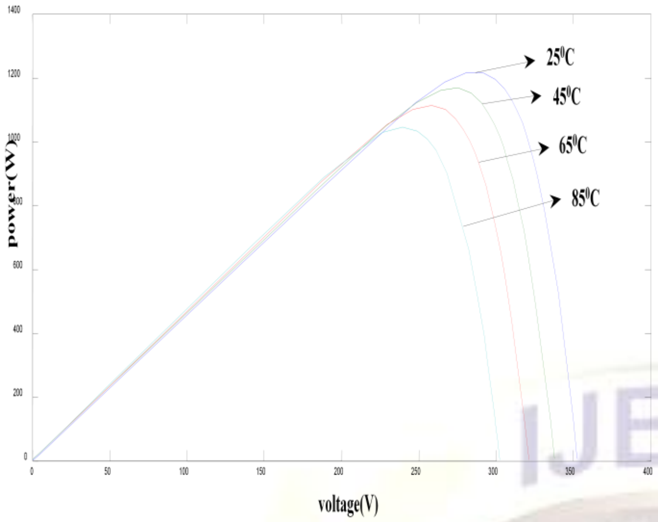

Fig8(b). P-V characteristics of Solar array for various temperature at a constant irradiance of 1000W/m^2.

3. BOOST CONVERTER

The output voltage can be greater than the input voltage V_{in} (solar array voltage).The switch S operates at high frequencies to produce a chopped output voltage [12]. The power flow is controlled by adjusting the on/off duty cycle of the switching. The average output voltage is determined by the equation,

$$\frac{V_o}{V_{in}} = \frac{T}{T_{off}} = \frac{1}{1-D} \qquad (8)$$

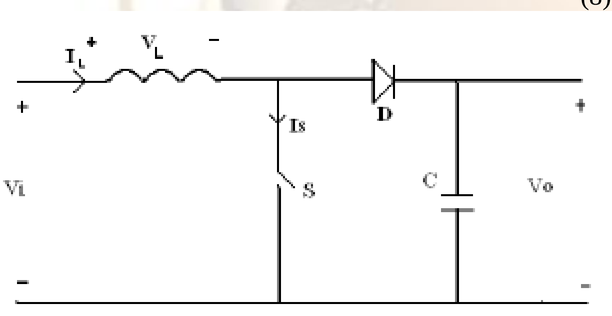

Fig.9. Boost Topology

Boost converter which boosts the voltage to maintain the maximum output voltage constant for all the conditions of temperature and solar irradiance variations. A simple boost converter is as shown in Figure9.

IV. MPPT TECHNIQUES

4.1. Open Circuit Voltage method

This method uses V_{OC} to calculate V_{MP}. Once the system obtains the VOC value, VMP is calculated by the equation 9.

$$V_{MP} = k \times V_{OC} \qquad (9)$$

The k value is typically varies from 0.70 to 0.80. It is necessary to update VOC occasionally to compensate for any temperature changes. It uses fraction of open circuit voltage to determine the modules voltage at the maximum power point. The open circuit voltage algorithm is based on the observation from V-I curves that the ratio of the array's maximum power voltage (V_{mp}) to its open circuit voltage (V_{oc}) is approximately constant. Here the factor is always <1.The solar array is temporarily isolated from the MPPT and a V_{oc} measurement is taken.

4.2 Short Circuit Current method

The short circuit current method uses a value of ISC to estimate IMP.

$$I_{MP} = k \times I_{SC} \qquad (10)$$

This method uses a short load pulse to generate a short circuit condition. During the short circuit pulse, the input voltage will go to zero, so the power conversion circuit must be powered from some other source. One advantage of this system is the tolerance for input capacitance compared to the VOC method. The k values are typically close to 0.9 to 0.98

4.3 Perturb and Observe (P&O) method

A P&O method is the most simple, which moves the operating point toward the maximum power point periodically increasing or decreasing the PV array voltage by comparing power quantities between in the present and past. The block diagram of P&O method is illustrated in Fig. 10.

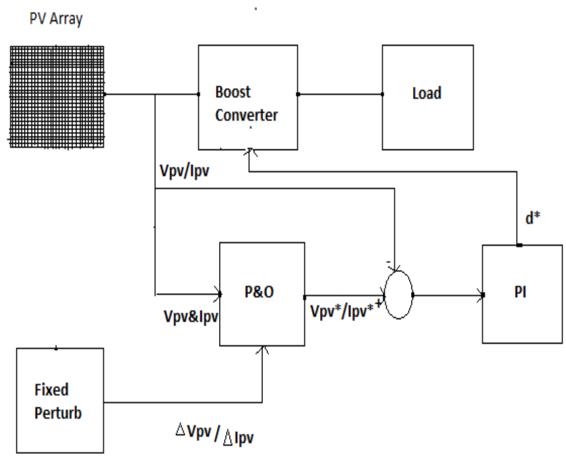

Fig.10. Block diagram of P&O MPPT

If the power increased, the perturbation is continuous in the same direction in the next perturbation cycle, otherwise the perturbation direction is reversed. This way, the operating point of the system gradually moves towards the MPP and oscillates around it in steady-state conditions. Large perturbation step sizes yield fast tracking of the MPP under varying atmospheric conditions but result in reduced average power conversion in steady state due to large oscillations around the MPP. Hence the famous tradeoff problem between faster response and steady-state oscillations is inherent. Moreover, the perturbation is not generic. In order to overcome all this, high performance P&O technique is proposed.

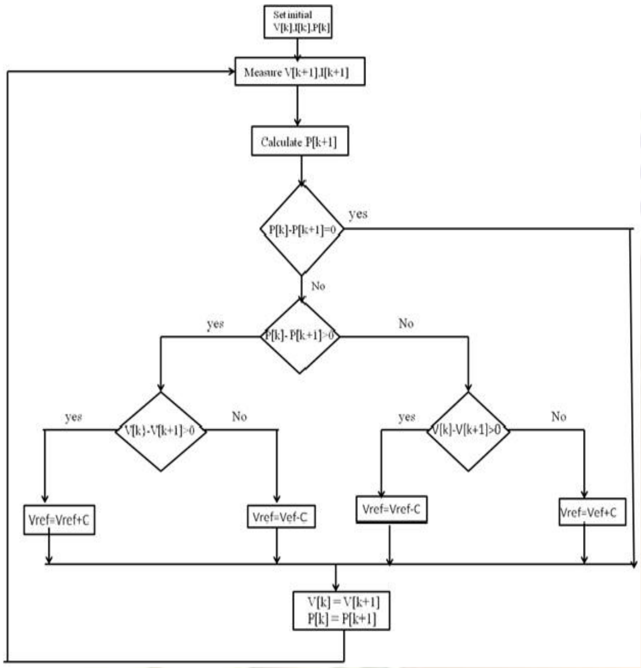

Fig11.Flow chart diagram of P&O MPPT method

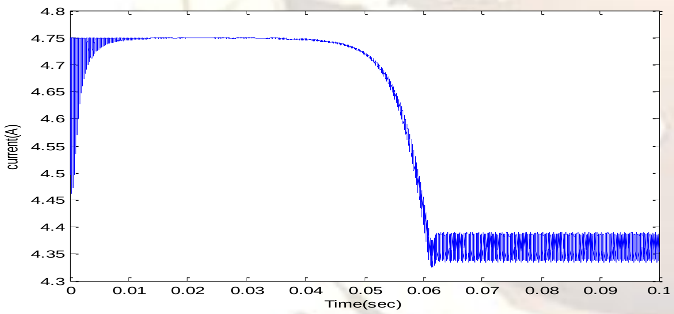

Fig12.(a). PV array output current for P&O MPPT technique

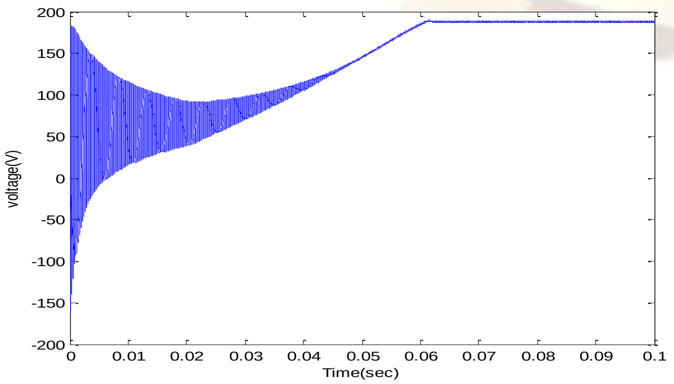

Fig12(b). PV array output voltage for P&O MPPT technique

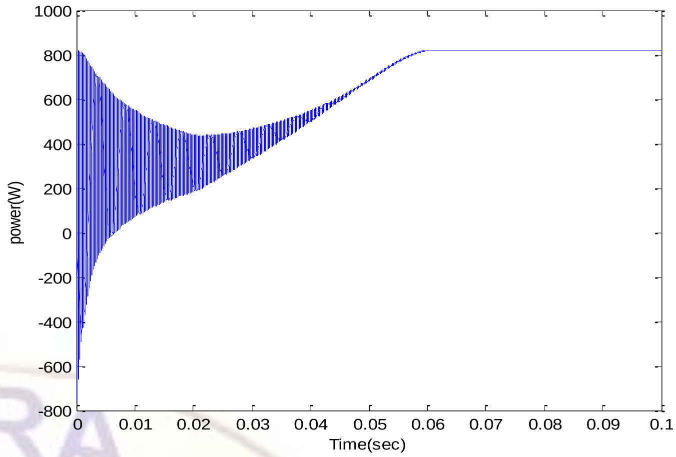

Fig12(c). PV array output power for P&O MPPT technique

The response with perturbation and observation (P&O) MPPT Technique waveforms are 12(a) PV array output current 12(b) PV array output voltage 12(c) PV array output power at temperature=25°c and solar irradiation =1000W/m^2.

S. No	MPPT Technique	Voltage (V)	Current (A)	Power (W)	Efficiency (%)
1	Without MPPT	288.40	1.748	504.10	50.41
2	P & O	188.4	4.353	820.1	82.01

Table5. Comparison of MPPT Techniques at a temperature of 25^{0}C and irradiance of 1000W/m^2

6. CONCLUSION

The maximum power point technique is used with PV system to improve its conversion efficiency. To eliminate mismatch between the load line and V-I characteristic, an MPPT control algorithm is necessary. This paper proposes design and modeling of photo voltaic system, simple boost converter and P&O MPPT Technique. The PV cell output voltage varies with atmospheric parameters such as temperature and irradiation. In order to operate PV array at MPP we need an interface system between PV array and load called MPPT. The OC & SC methods are simple but do not accurately track the MPP. In order to overcome the drawback of above methods P&O method is proposed.

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