ASSESSMENT OF DIFFERENT MPPT TECHNIQUES FOR PV SYSTEM

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Abstract: *Photovoltaic (PV) energy, which has proven to be environmentally friendly and sustainable compared to traditional energy sources, has gained widespread attention in recent years. PV technology is one of the fastest growing energy technologies in the world owing to its abundant availability. But unfortunately, the cost of PV energy is higher than that of other electrical energy from other conventional sources.Therefore, a great deal of research opportunities lie in applying power electronics and control technologies for harvesting PV power at higher efficiencies and efficient utilization. Simulation/coding and control studies of a PV system require an accurate PV panel model. Further, for efficient utilization of the available PV energy, a PV system should operate at its maximum power point (MPP). A maximum power point tracker (MPPT) is needed in the PV system to enable it to operate at the MPP. Maximum power point trackers (MPPTs) play an important role in photovoltaic (PV) power systems because they maximize the power output from a PV system for a given set of conditions, and therefore maximize the module efficiency. Thus, an MPPT can minimize the overall system cost. MPPTs find and maintain operation at the maximum power point, using an MPPT algorithm. This paper presents a comparative study of three widely-adopted MPPT algorithms, and assessment of each method using MATLAB coding as well as simulink.*

Key words: *[MPPT] maximum power point tracking, [P&O] Perturb and Observe, [PV] Photovoltaic panel.*

1. Introduction

Solar energy is one of the most important renewable energy sources. As opposed to the conventional non renewable sources such as gasoline, coal, etc. solar energy is clean, inexhaustible and free. Unfortunately, PV generation systems have two major problems: the conversion efficiency in electric power generation is low and the amount of electric power generated by solar module changes con-tinuously with weather conditions. Moreover, the solar cell V-I characteristic is nonlinear and changes with irradiation and temperature. In general, there is a point on the V-I or V-P curve only, called the Maximum Power Point (MPP), at which the entire PV system operates with maximum efficiency and produces its maximum output power. The location of the MPP is not known, but can be located, either through calculation models or by search algorithms. Maximum Power Point Tracking (MPPT) techniques are used to maintain the PV module's operating point at its MPP.

Many MPPT techniques have been proposed in the literature; like Incremental conductance method, Perturb and Observe method, Artificial Neural Network method, the Fuzzy Logic method, etc..But, The tracking of MPP has not yet been done ,on the P-V or I-V Curve and conventional P&O has drawbacks such as low tracking speed do not track the exact maximum power point during sudden changes of irradiation and temperature.So in this paper Modify the conventional P&O method and evaluate the INC,P&O and MP&O methods using MATLAB Programming/Simulink Results.

2. Modeling of PV Panel

Accurate modeling of a photovoltaic cell is an important requirement for designing an efficient PV system since photovoltaic cell is the basic element of a PV system. In the past, a number of research works have been directed on both modeling of PV module and on topological descriptions which are used in either isolation or integrated to a grid. Choice of topology system is also important for successful modeling of a PV module.A number of mathematical models of PV cell such as ideal model, two-diode model and single-diode model are available in literature. According to law of Physics, an ideal model of the PV module can be represented by a photo-generated current source Iph and a diode both in parallel to each other (Fig.1 (a)). The diode *D* represents the p-n junction of the PV module and current through this diode Id represents the escaping current through the p-n junction due to the diffusion mechanism. This model assumed to be lossless and is the simplest model. But this model does not represent an accurate structure of a PV module.

To improve the accuracy, a series resistance Rs of the PV module has been considered in as shown in Fig.1 (b) which represents the conductance loss. To further increase the accuracy, another resistance Rsh that represents the leakage current in the p-n junction has been added to Fig.1 (c) which is represented in Fig.1.(c) A second diode has been added to the structure of the

Fig.1 (c) in order to increase the modeling accuracy further and the modified model is called a two-diode model as shown in Fig.1.(d). In this model, current Id1 through diode D1 represents the diffusion current due to major charges while current Id2 through diode D2 represents the recombination current due to minor charges. Although behavior of a two-diode model closely matches with that of the physical PV module but the model is non-linear and complex. Its mathematical analysis is very difficult.

The single diode model of PV module is although non-linear but simple in structure than that of the two-diode model. Hence, analysis of this model is easier than that of the two-diode model. It also responds quickly to any changes in the system conditions. On comparing the reported different models of PV module, the single-diode-five-parameter model represented using five parameters namely series resistance (Rs), shunt resistance (Rsh),diode-ideality factor (*a*), dark saturation current (I0) and photo-generated current (Iph) is suitable in maintaining optimized balance between imitations of the physical PV module and the ease of implementation in mathematical analysis hence widely used. Therefore, a single diode five-parameter model is considered in this work.

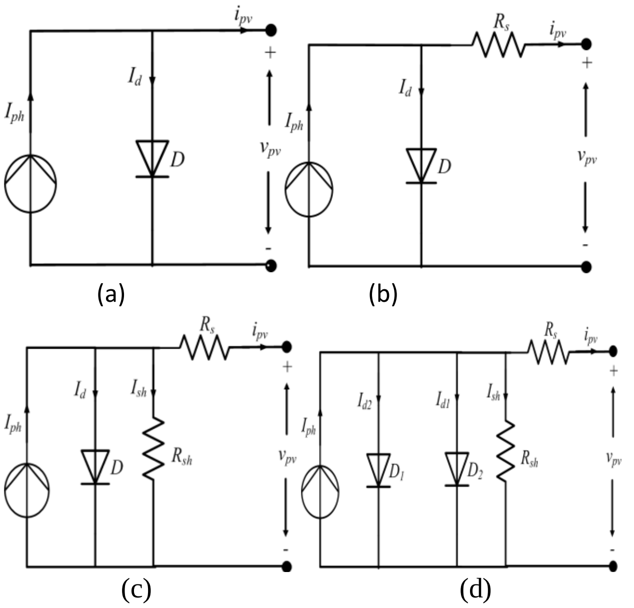

Figure 1: (a) Ideal Model, (b) Single-diode-four-parameter Model, (c) Single-diode-five-parameter Model and (d) Two-diode Model of a PV module

3. MPPT Algorithms

PV module would have a maximum power point for given temperature and insolation. If a load line crosses at this point, maximum power would be transferred to the load. When temperature /insolation changes, maximum power point changes.Since the load line does not change, it does not pass through the maximum power point and hence maximum power cannot be transferred to the load. To achieve the transfer of maximum power, it requires that the load follows the maximum power point and this is achieved by translating the actual load line point to maximum power point by varying the duty cycle of DC-DC converter. We can vary the DC-DC converter duty cycle (D) manually to operate PV system at maximum power point (V_{mpp}, I_{mpp}). As the temperature and incident solar radiation changes throughout the day we should have to set duty cycle (D) automatically to track the maximum power point automatically. There are various techniques which adjust duty cycle (D) automatically which can be implemented in analog or digital method.

3. (i) Incremental conductance method

The Incremental Conductance (IC) algorithm is based on the observation that the following equation holds at the MPP **:** $(dI_{PV}/dV_{PV})+(I_{PV}/V_{PV})=0$ (1)

where I_{PV} and V_{PV} are the PV array current and voltage, respectively. When the operating point in the *P*-*V* plane is to the right of the MPP, it is verified $(dI_{PV}/dV_{PV}) + (I_{PV}/V_{PV}) < 0$, whereas when it is to the left of the MPP this $(dI_{PV}/dV_{PV})+(I_{PV}/V_{PV})>0$. The MPP can thus be tracked by comparing the instantaneous conductance I_{PV}/V_{PV} to the incremental conductance *dIPV/dVPV*. Therefore, if the quantity $(dI_{PV}/dV_{PV}) + (I_{PV}/V_{PV})$ is more than ε, its sign means a power production decrement and indicates the correct direction of perturbation leading to the MPP. Once MPP has been reached, the operation of PV module is maintained at this point and the perturbation remains unless a change in dI_{PV} is noted. In this case, the algorithm decrements or increments the PV array voltage V_{PV} to track a new MPP. The increment size determines how fast the MPP is tracked.

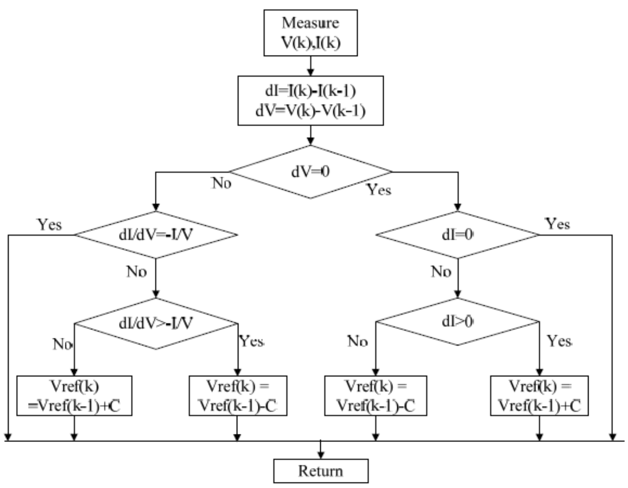

Figure 2: Flowchart of incremental conductance MPPT method.

Advantages:
• Good yield under rapidly changing atmospheric conditions
Disadvantages:
• Efficiency is somewhat less than P&O
• Requires complex and costly control circuits
• Needs four sensors to accomplish its MPPT action
• Here output voltage and current signals of PV panel oscillate even at steady state

3. (ii) Perturb and Observe algorithm

The hill climbing (perturb and observe) algorithm is the most popular method used in practice. Its popularity is due to the simplicity of implementation. It has been extensively studied and there are many versions with minor discrepancies. It is an iterative process to reach the maximum power point. The operating point is perturbed and then the system response is measured to determine the direction of the next perturbation, increasing the PV voltage, while in the left hand side of the MPP, increases the PV output power. On the contrary, in the right hand side of the curve, decreasing the voltage increases the power. So after a perturbation, if the power increases the subsequent perturbation will continue in the same direction. If the power decreases then the direction is reversed. The hill climbing method is therefore also referred to as the Perturb and Observe (P&O) method. This algorithm is summarized in a flowchart in Figure 3.

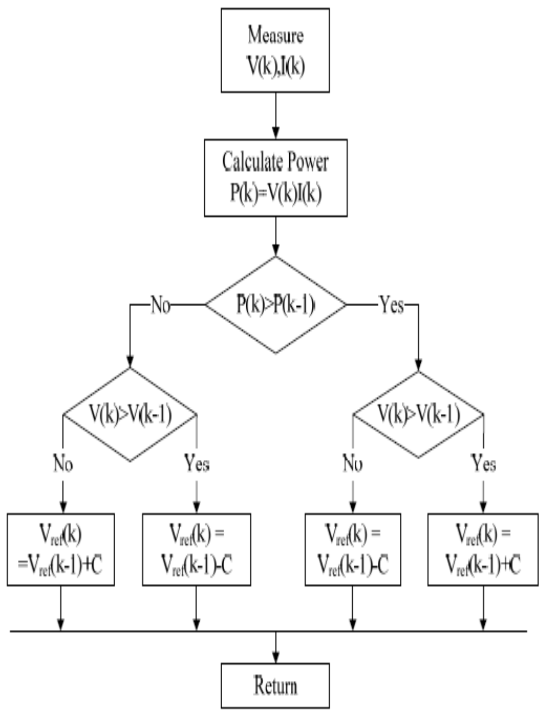

Figure 3: Flowchart of hill-climbing (P&O) algorithm.

The algorithm determines the reference voltage Vref (k) for the PV array voltage controller.The power at the current instant P (k) is calculated from the instantaneous voltage and current V(k) and I(k) respectively. Next P (k) is compared with the power of the previous instance P(k-1). If the power has increased, then the algorithm checks the last change in the PV array voltage and continues to change it in the same direction, either by adding or subtracting incremental value C to the reference voltage. However, if the power has decreased, the change to the voltage is set in the opposite direction.

This process is repeated till the system reaches MPP and then it oscillates near the MPP. The magnitude of oscillation depends on the magnitude of the perturbation and the frequency of update. The algorithm can be optimized to reduce the oscillation. One drawback of this method is that it fails under rapidly changing irradiance and environmental conditions. This occurs when the change in power due to atmospheric conditions is larger and in the opposite direction than the changes due to perturbation caused by the algorithm, which results in the operating point shifting in the opposite direction.
Advantages:
• Accurate result
• Reliable and efficient technique
• Independent of the panel properties and characteristics
Disadvantages:
• Accuracy and required time are dependent on size of perturbation
• Not suitable for fast changing environmental conditions
• Output voltage and current signals of PV panel oscillate even at steady state

So, for eliminating the drawbacks of these two methods we go for modified Perturb and Observe Method.

3. (iii) Modified P&O method

The modified P&O method is implemented based on the conventional P&O MPPT method by removing the wrong control phenomenon during rapidly irradiance changing period. As shown in Fig. 5, the concept of P&O method is simple to observe the power variation and PV voltage reference after the PV voltage is observed. Basically, it is based on the assumption that the power variation is occurred by only PV voltage perturbation. Practically, power variation of PV array output could be caused by both the control of PV inverter and the environmental condition like irradiance variation. If the conventional P&O method is used for this rapidly changing irradiance condition from irradiance1 at t1to irradiance2 at (t+Δt) in Fig. 4, the PV inverter may fail to track its maximum power due to the irradiance changing.

Specifically, PV inverter by the conventional P&O method commands the PV voltage to be increased fromV1 to V2 under irradiance1 at t1, assuming that the previous MPPT command is to increase the PV voltage. However, after a short time Δt, the next operating point stays at point C not point B in Fig. 4 because the irradiance changes rapidly.

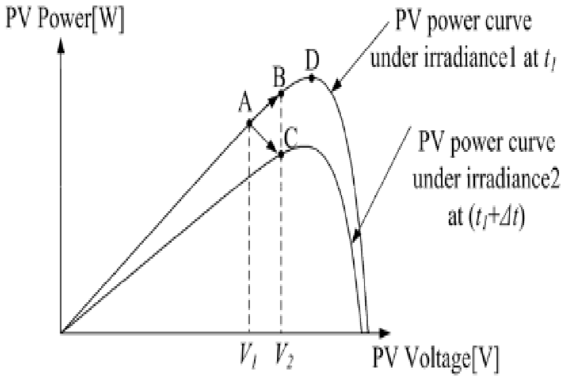

Figure4: Malfunction phenomenon of the conventional MPPT control when the irradiation is changing from irradiance1 to irradiation2

This phenomenon can be summarized that PV power is decreased after the PV voltage command is increased. Thus, the next PV voltage command by the conventional P&O algorithm would be decreased. This is the reverse way to track the real maximum power point (MPP), which is point D in Fig. 4. This is why the conventional P&O method fails to track MPP under rapidly changing irradiance. In response to this irradiance disturbance, the modified P&O method is presented to differentiate the power variation caused by between irradiance change and MPPT control. As shown in Fig. 5, the modified P&O method adds an additional measurement of PV array power at the mid-point of MPPT control period. PV power for MPPT control is calculated on average in order to reduce the noise influence. The power difference dP 0.5 in (2) between the mid-point power P(k-0.5) and the starting power P(k-1) of MPPT control contains both power change by MPPT control and irradiance change. However, the value dP1 in (3) contains only the power caused by irradiance change. As a result from (2) to (4), a power difference dP caused by the only MPPT control command can be calculated.

dP0.5=P (k-0.5)-p(k-1) (2)

dP1=P (k)-p(k-0.5) (3)

dP =dP0:5- dP1 (4)

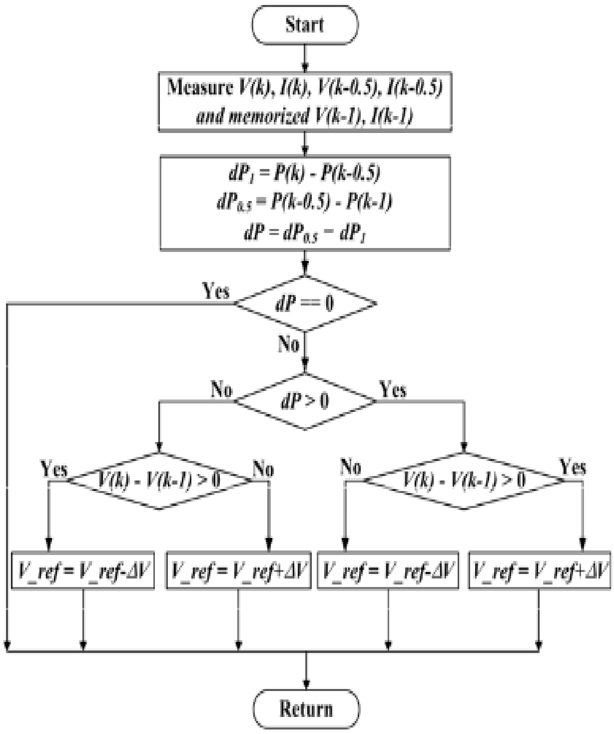

Figure5:Flow charts of the modified P&O method

Based on the power variation by only MPPT command in (4), the MPPT controller for PV inverter can track the right direction to find the maximum power point of PV module

Advantages:

- Accurate result
- Tracking speed high
- Efficiency is more compared to INC and P&O Method

4. Results and Discussions

Case1: Different irradiations and constant temperatureof25 ^{0} C.

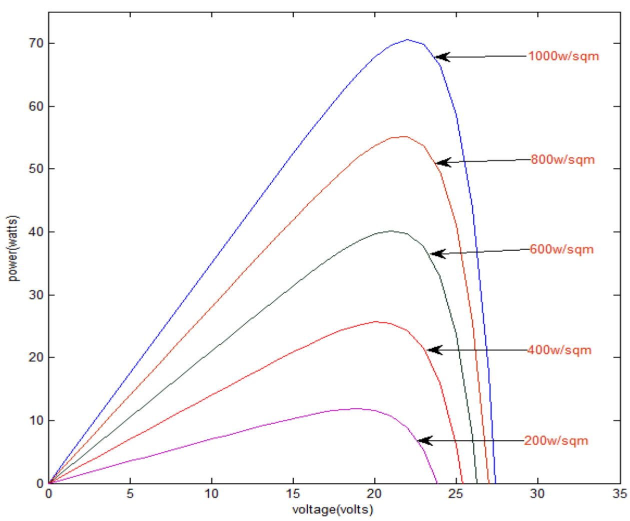

Fig (a): P-V characteristics

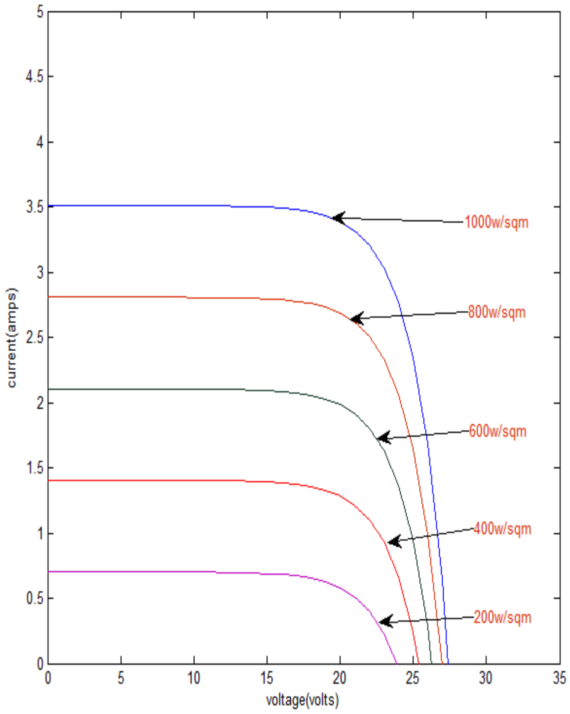

Fig (b): I-V characteristics

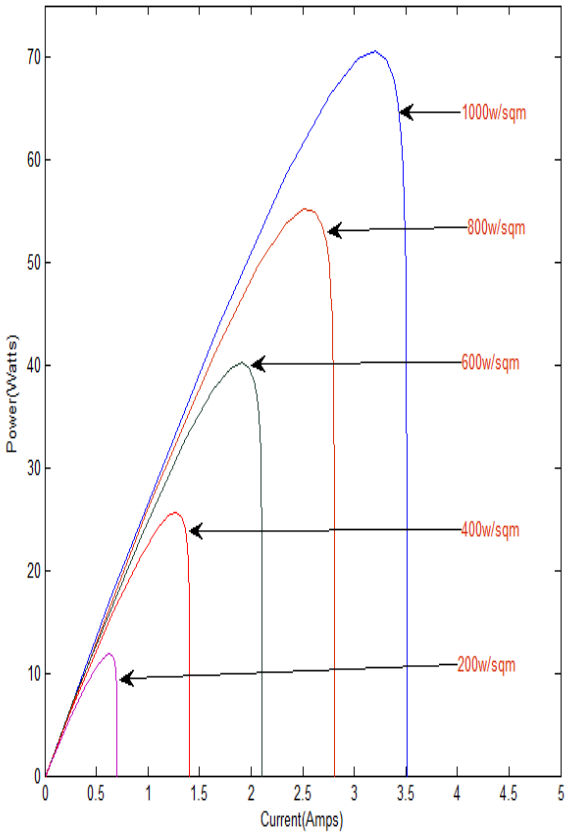

Fig (c): P-I characteristics

Case2: Different temperatures and constant irradiation of 1000w/sqm

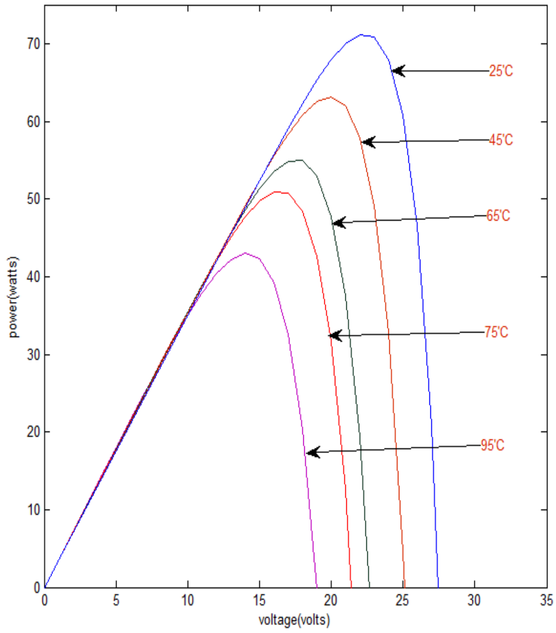

Fig (d): P-V characteristics

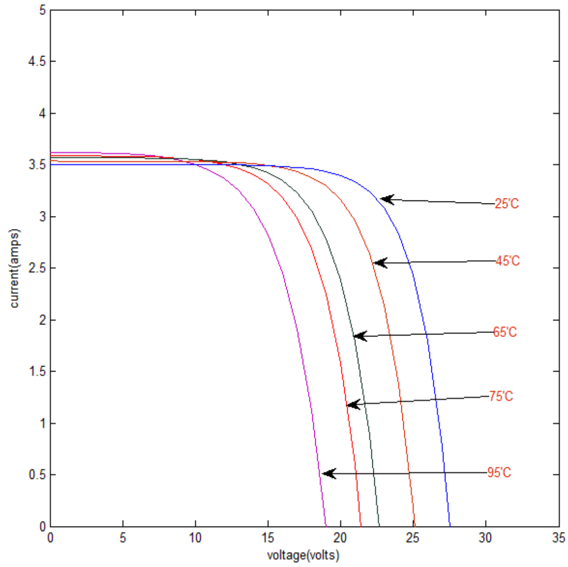

Fig (e): I-V characteristics

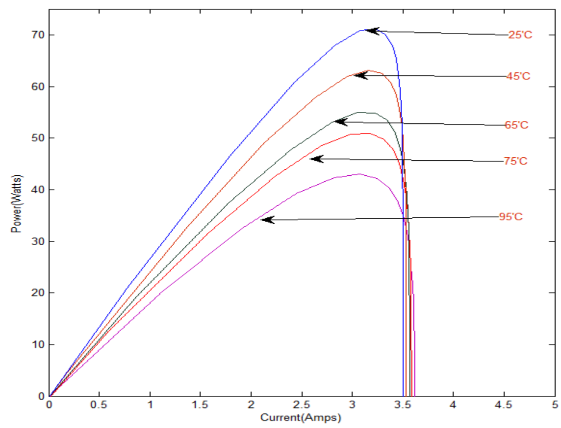

Fig (f): P-I characteristics

Tracking of Maximum Power Point

P-V characteristics for different irradiation levels at constant temperature of 25 ^{0}C .

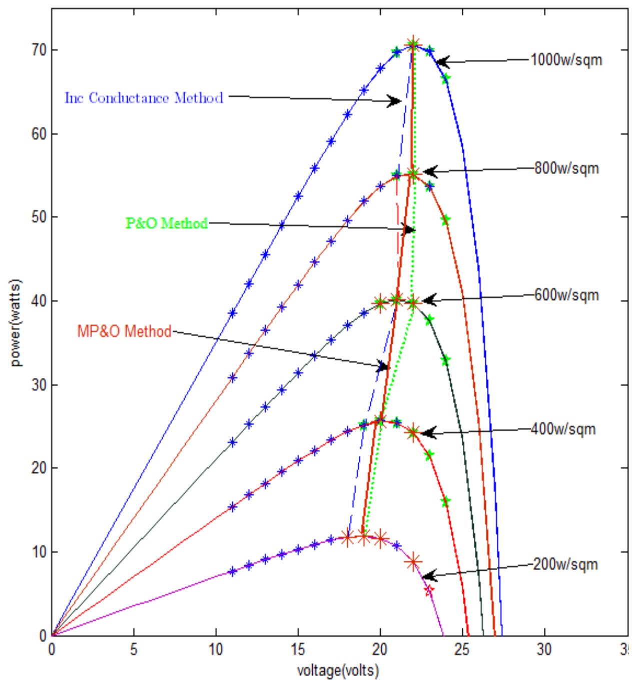

Fig (g): Tracking of Maximum Power Point using Inc, P&O and MP&O Methods for different irradiation levels and constant temperature i.e, 25 ^{0}C .

P-V characteristics for different temperatures at constant irradiation of 1000w/sqm.

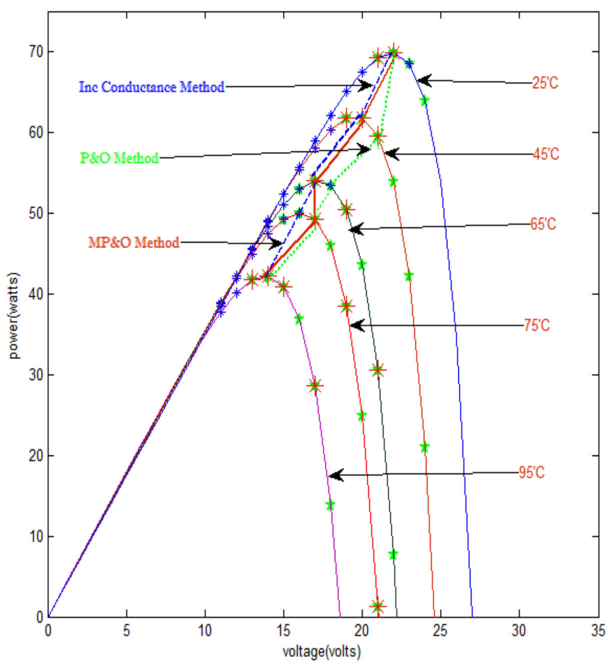

Fig (h): Tracking of Maximum Power Point using Inc, P&O And MP&O methods for different temperature levels and constant irradiation i.e,1000w/sqm

Comparison of INC, P&O and MP&O MPPT Techniques

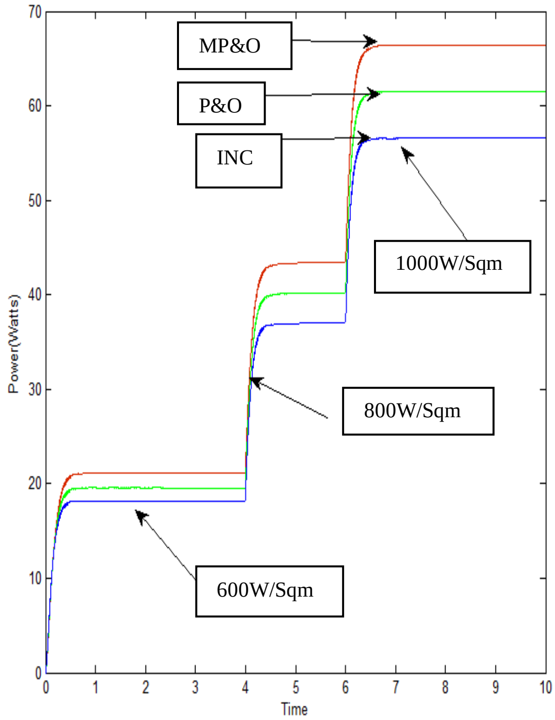

Fig (i): Tracking of Maximum Power Point using Inc, P&O And MP&O methods for different irradiations and constant temperature of 25 ^{0}C , and a particular load

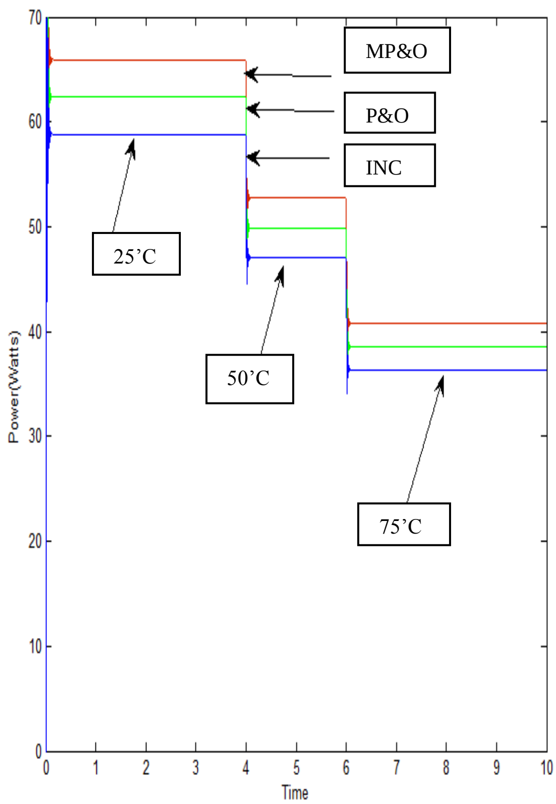

Fig (j): Tracking of Maximum Power Point using Inc, P&O and MP&O methods for different temperature levels and constant irradiation i.e,1000 w/sqm

Table1: Time Comparison of INC,P&O and MP&O :

S.no.	Technique	Time to track MPP for different irradiations(sec)	Time to track MPP for different temperatures(sec)
1	INC	14.917	17.065
2	P&O	14.012	15.967
3	MP&O	2.947	4.631

Table2: Power Comparison of INC, P&O and MP&O Techniques for different irradiations and Temperatures:

Technique	Power For different irradiations			Power For different temperatures		
	1000	800	600	25	50	75
INC	56.55	36.99	18.18	58.82	47.04	36.34
P&O	61.46	40.22	19.57	62.38	49.89	38.54
MP&O	66.37	43.44	21.14	65.95	52.74	40.75

Table3: Efficiency Comparison of INC, P&O and MP&O Techniques:

Technique	Conversion Efficiency (%)	
	Irradiation of 1000w/sqm	Temperature of 25’C
INC	80.7	84
P&O	87.8	89.11
MP&O	94.8	94.214

5. Conclusion:

The existing methods Incremental, perturb and observe and proposed method modified perturb and observe methods are compared. Here,the results indicate that PV conversion system using modified perturb and observe method which has higher conversion efficiency and it tracks the exact maximum power point at less time with higher tracking speed than Incremental conductance,perturb and observe method.Therefore, the modified Perturb and Observe method was best preferred due to its higher tracking speed and high conversion efficiency.

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