A Comparative Evaluation of Existing Mppt Algorithms and Development of a Hybrid Algorithm for Photovoltaic Systems

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Abstract— *This Research paper is about a comparative evaluation of different existing algorithms for Maximum Power Point Tracking (MPPT) of photovoltaic (PV) systems, and developing of a new hybrid-algorithm. Solar panel is a non linear power source and its output power depends on the thermal operating point and solar irradiation level. In order to increase the efficiency of the solar panel it is important to maintain the system on the maximum power point (MPP). A great deal of researches and experiments have been done to find efficient algorithms to keep the system on the maximum power point. This paper investigates the relative performances among Perturbation and Observation (P&O), dp-Perturbation and observation (dp-P&O), Incremental Conductance (INC-CON), and Constant Voltage (CV) methods of algorithms. Relative advantages, disadvantages and limitations of these methods are discussed, and supported by the results of simulation in MATLAB. A new hybrid algorithm is proposed for enhanced performances.*

Keywords— *Maximum power point tracking, MPPT, PV systems, Comparative evaluation*

I. INTRODUCTION

Conventional energy sources are rapidly depleting and the solar energy is significantly becoming more important compare to other renewable energy sources. Numbers of larger scale solar power systems are proposed as per the world renewable energy forecasting. It has clean, pollution free and inexhaustible energy generation. Photo voltaic system is gaining increase of importance in renewable energy due to the advantage as per the absence of fuel cost, little maintenance and no noise and wear due to the absence of moving parts . Therefore most of the researches on the photovoltaic systems power generations have received significant attention among the researches in renewable energy field. Solar energy is a non linear power source and its output current and voltage (power) depend on the thermal operating point and solar irradiation level. In order to increase the efficiency of the solar panel, maintaining the system on maximum power point (MPP) is utmost important. Great deal of researches and experiments have been done to find the efficient algorithms to keep the system on the maximum power point. As the market is now flooded with varieties of maximum power point tracking (MPPT) systems. Maximum power point tracking algorithms are the recently most interested research topic among the researchers. Many of MPPT algorithms have been proposed as for the non artificial intelligence. Constant voltage tracking method (CVT), Fraction Open Circuit method (OCV), Hill climbing and
Perturb and Observation method (P&O), dp-P&O method, Incremental conductance method (INC-CON), Variable step size method based on incremental method, Fussy control method are introduced.[5][7]. In this paper it is focused on comparing the available selected algorithms of their advantages, disadvantages and weaknesses.

II. PV ARRAY CHARACTERICTS AND MODELS

Photovoltaic cells are devices that absorb sun light and convert that solar energy into electric energy. Solar cells are commonly made from silicon.

The basic working principle of the PV array is the photovoltaic effect of semiconductor PN junction. The complex physics of a PV cell can represent by the equivalent electrical circuit as shown in figure 1[5]

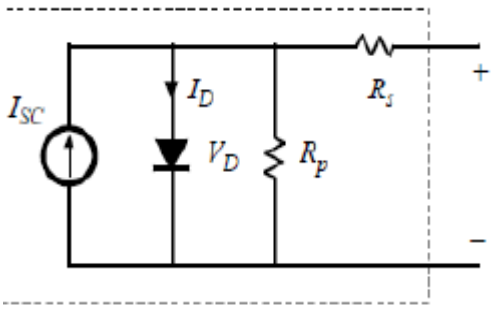


Fig .1 PV module equivalent electrical circuit

The circuit contains a source with a diode, a shunt and a series resistance. The current I_D is mainly responsible for producing the non linear I-V curve characteristics of the PV cell.[1]

Using KCL:

$$I_{sc} - I_D - \frac{V_D}{R_P} - I_{PV} = 0 \qquad (1)$$

Diode characteristic:

$$I_D = I_0 \left(e^{V_D/V_T} - 1 \right) \qquad (2)$$

KVL:

$$V_{PVcell} = V_D - R_s I_{PV} \qquad (3)$$

Where:
I_{SC}: Short Circuit Current of PV cell
I_D: Diode Current
I_o: PN junction Reverse saturation current
I_{PV}: PV Current
V_{PV}: PV voltage
V_D: Diode Voltage
R_S: Series resistance
$R_{P:\ Parallel}$ resistance

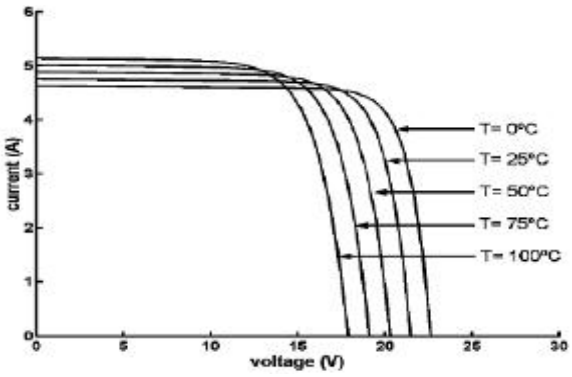


Figure.2 (a) Current vs Voltage characteristics

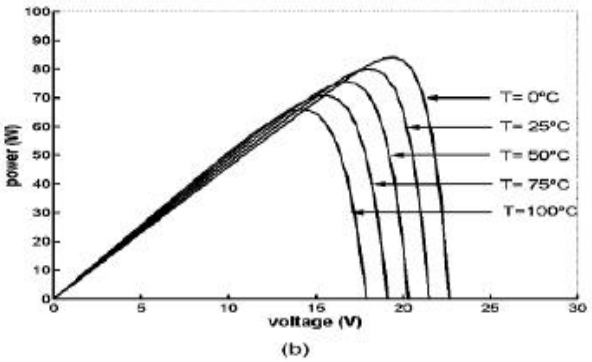


Figure.2. (b) Power Voltage characteristics

Figure 2 shows that the behaviour of Photo Voltaic array output voltage (Figure2 (a)) and current has not linear. Since output power characteristic also not linear (Figure 2(b)) , its required to maintain the solar panel at the maximum power point throughout the operation.

III. MPPT TECHNIQUES

A. Perturb and Observation Method (P&O)

Perturb and observation method is one of the most commonly used methods in practice. The P&O algorithm is operated by periodical perturbing. Incrementing and decrementing array terminal voltage and comparing output power with that of previous perturbation cycle. if the PV array operating voltage and power increase control system moves the PV array operating point to that direction otherwise opposite direction.[5] After the peak power is reached power at the next instance decreased and again it tries to move the max power point to the reverse direction. At the steady state it is toggled

between two sides of the peak value. In order to keep the power variation small, the perturbation size must be very small. [8] Perturbed and Observe is one of the so called 'hill climbing' MPPT method which are based on the fact that, on the voltage power characteristic, on left of the MPP the variation of the power against voltage dp/dv<o(see Fig 3) In figure 3 ,if the operating voltage of the pv array is perturbed in a given direction and dp/dv>0,it is known that the perturbation moved the array's operating point towards the MPP. The P&O algorithm would then continue to perturb the PV array voltage in the same direction if dp/dv<0, then the changes in the operating point moved the PV array away from the MPP and the P&O algorithm reverses the direction of the perturbation. Flow chart of the P&O algorithm shown in [2](Fig 3)

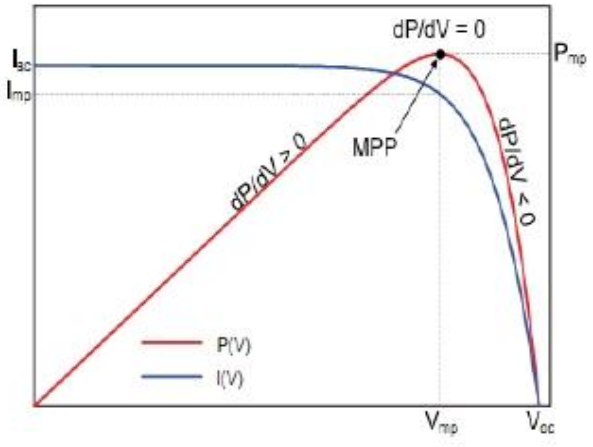


Fig .3. sign of dp/dv at position on the power characteristics of a module

The main advantage of P&O method is that it is easy to implement ,it has low computational demand, and it is very generic (can applicable to many systems and it does not required many information only measured voltage and current at the instantaneous times) , it is very simple structure and easy to implement.

There are some disadvantages or drawbacks experienced due to the perturbation and power loss and it can be failed to track in wrong direction with the MPP under fast varying atmospheric and environmental conditions, power tracked by the P&O method oscillates and perturbs up and down near the max power point. Efficiency is lesser power in low irradiation [2][8][5][7]

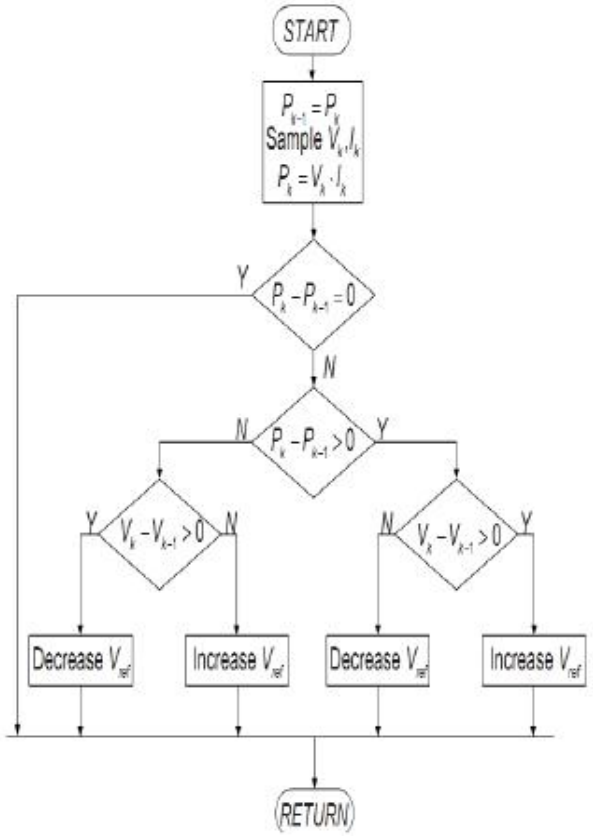


Figure 4: The flow chart of the P&O algorithm

B. Incremental Conductance Method (INC)

The theory of incremental conductance method is to determine the variation direction of the terminal voltage for PV modules by measuring and comparing the incremental conductance and instantaneous conductance of PV modules. The incremental conductance can determines that the MPPT has reached the max power point and stop the perturbing at operating point. The principle of this method is judge the certain condition shown in below equations [5].

$$\frac{dP}{dV} = \frac{d(IV)}{dV} = I + V\frac{dI}{dV} = I + V\frac{\Delta I}{\Delta V} = 0$$

$$-\frac{I}{V} = \frac{\Delta I}{\Delta V}$$

$$G_s = -\frac{I}{V}$$

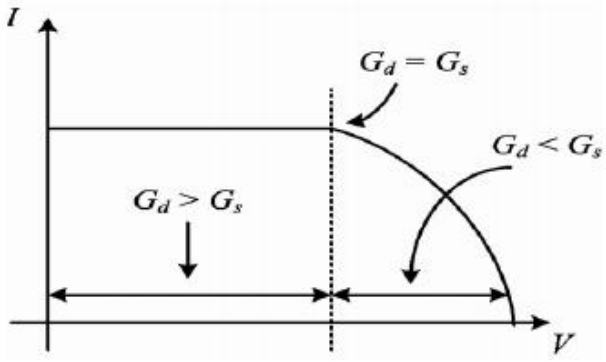
$$G_d = \frac{dI}{dV}$$

Therefore analysing the derivative, it can decide the system is operating in MPP or not or far from the MPP using below constrains described in below

$$\frac{dP}{dV} > 0 \quad \text{for} \quad V < V_{MPP}$$

$$\frac{dP}{dV} = 0 \quad \text{for} \quad V = V_{MPP}$$

$$\frac{dP}{dV} < 0 \quad \text{for} \quad V > V_{MPP}$$



The MPP can thus be tracked by comparing the instantaneous (ΔI / ΔV) to the incremental conductance. V_{ref} is the reference voltage at which the PV array is forced to operate It is maintaining same operation point until the any change of ΔI. The flow chart of this methodis shown in figure 5[5][7].

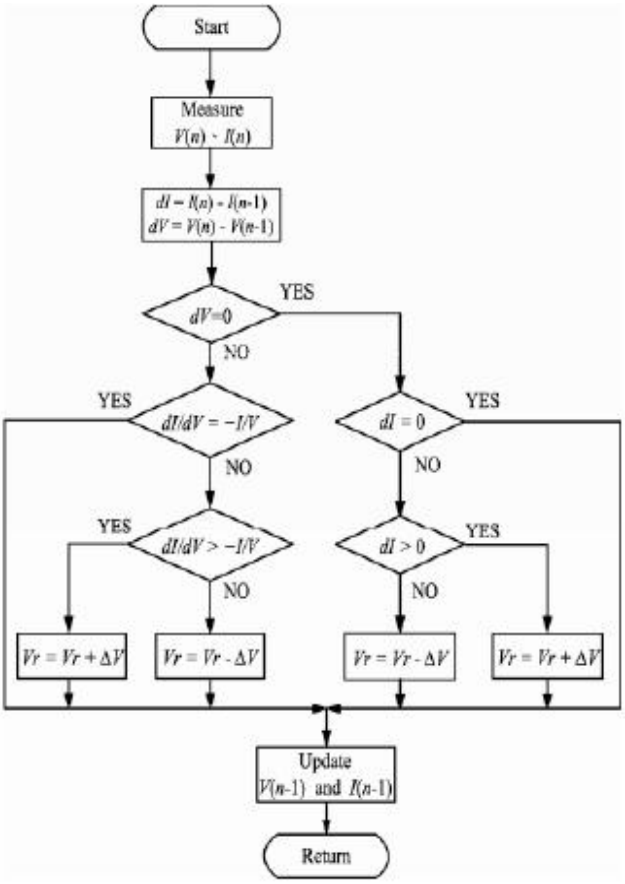


Figure.5. INC-CON method flow chart

The disadvantage of perturb and observation method to tracking difficulty of the peak power under rapid changing conditions is to some extent has overcome by the INC-CON method.[8] it can find the distance to the MPP & can determine when the max power point has reached and hence stop the perturbation Since it has higher efficiency than P&O method. At the higher irradiation level this method performs with higher efficiency[2] There are some drawbacks in this method such as performance in low irradiation levels(below 300W/m^2) and its completely failed to track under 50W/m^2 of irradiation. There are some marginal errors due to the equality of two terms and it leads to decrease the sensitivity of the system. But still there are some oscillation around MPP and wrong direction tracking due to sudden irradiation level change can be experienced in this method.

C. dp P&O Method

P&O method tracked wrong direction in rapid changing of irradiation level since dp P&O method to overcomes that drawback. If the changes in intensity of irradiation cause bigger change of power than one caused to increment in voltage, the MPPT can get confused, as it will intercept the change in the power as an effect of its own action. This is illustrated in figure 6[2].

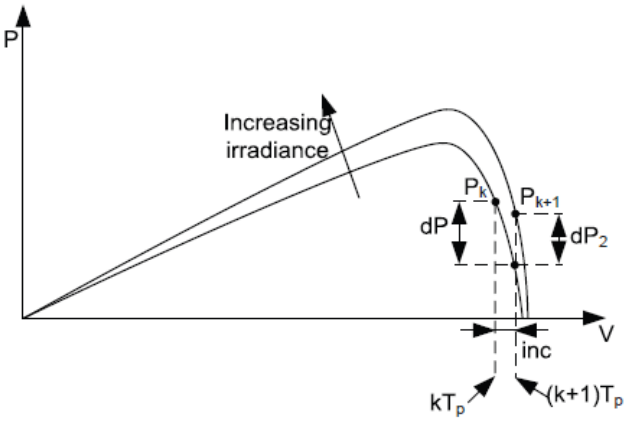


Figure 6 (a)

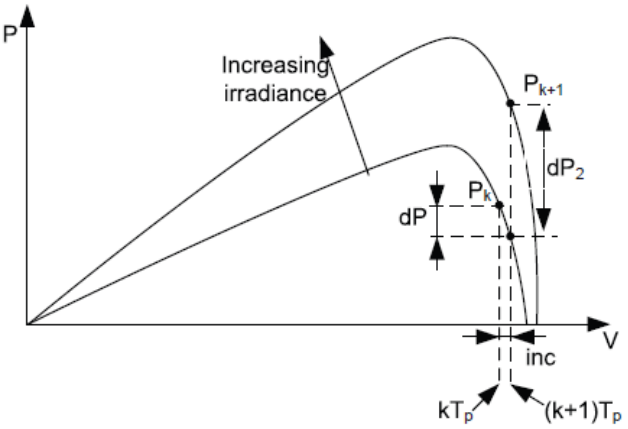


Figure 6 (b)

In the case of slow irradiation changed P&O method is able to track the right direction (a),but in the case of rapidly changing condition its unable to track the right direction (b). dp P&O method is changed from P&O method by adding additional measurement of power in middle of the MPPT sampling without any perturbation.

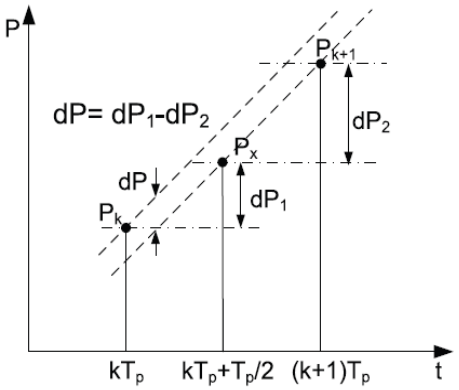


Figure 7 Measurement of power between two MPPT sampling instances

As shown in figure 7 power between P_x and p_{k+1} reflect only the environmental changes as no action has taken by the MPPT. Difference between P_x and P_k contains the changes in power caused by perturbation of MPPT plus environmental effect. Therefore assuming that rate of change of irradiation is constant over sampling period of the MPPT dp caused by purely due to MPPT command is calculated. The efficiency gain of dp P&O method over the classical P&O method has been calculated as 2.4% (power feed forward was switched on)flow chart of the developed dp-P&O method is shown in figure.8[2].

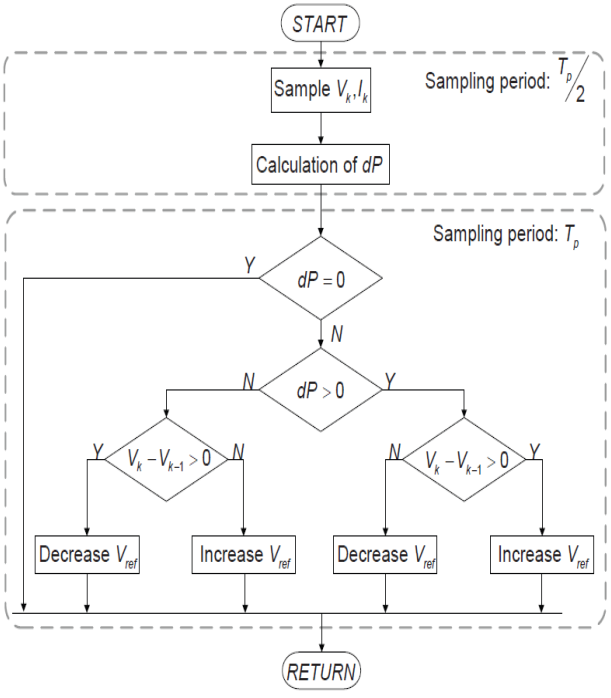


Figure.8 Flow chart of dp P&O Method

D. Constant Voltage method

In this method MPPT momentarily set the PV array current to zero to allow the measurement of Voc and the operating voltage is fixed at 76% of open circuit voltage value.(76% for the crystalline silicon panel and this value changes as per the pv panel family)operating point maintain set amount of time &after cycle is repeated. This is very simple method and major advantage of this method improves performance higher than P&O and INC methods in lower irradiation level. MPP is always not fixed at 76% of level and energy wasted due to open circuit voltage test are the draw backs of method as mentioned in the literature[5].

E. Proposed Algorithm

Constant voltage method shows higher efficiency at lower irradiation levels. But it shows lesser efficiency at higher irradiation levels.[5] As well as most of the hill climbing algorithms above discussed oscillate around MPP and fail to respond accurately at higher irradiation changes (It can direct to wrong direction) dp P&O method can respond to some extent accurately than other method in higher irradiation changes. But it also fails to track in lower irradiation levels.

Proposed algorithm (see figure 9)is combination of dp P&O method and Constant voltage method in order to overcome above mentioned draw backs such as tracking wrong direction in higher irradiation changes and lower efficiency in higher irradiation levels.

As shown in figure the figure 2.2 the instantaneous Irradiation levels of the particular photovoltaic materials can be identified by short circuit current as Short circuit current demonstrate the irradiation level and this leads to a solution to overcome above drawbacks by operating efficient algorithm as per the irradiation conditions. At the lower irradiation level it operates with constant voltage method and higher irradiation level it operates with the dp P&O method.

IV. CONCLUSION

The purpose of this paper is to study and compare the advantages, shortcomings of four of the available MPPT algorithms P&O method, dp P&O method, INC-CON method and Constant voltage method. P&O method has simple algorithm with a higher accuracy in high

irradiation levels .Since P&O is a hill climbing method, it can oscillates around the MPP which can be minimized by reducing step size of the reference voltage and increasing perturbation frequency. Incremental conductance method has advantage of exact perturbing and tracking direction and steady maximum power operating voltage. Even though this method is not suitable for rapidly changing environmental conditions and dp-P&O method can overcomes particular draw back in some extent but both of this algorithms show lesser efficiency in lower irradiation levels. In that case Constant voltage method can easily overcome that problem . By considering those facts new algorithm is proposed by selecting dp P&O method at higher irradiation levels and constant voltage method at lower irradiation level as shown in figure 9.

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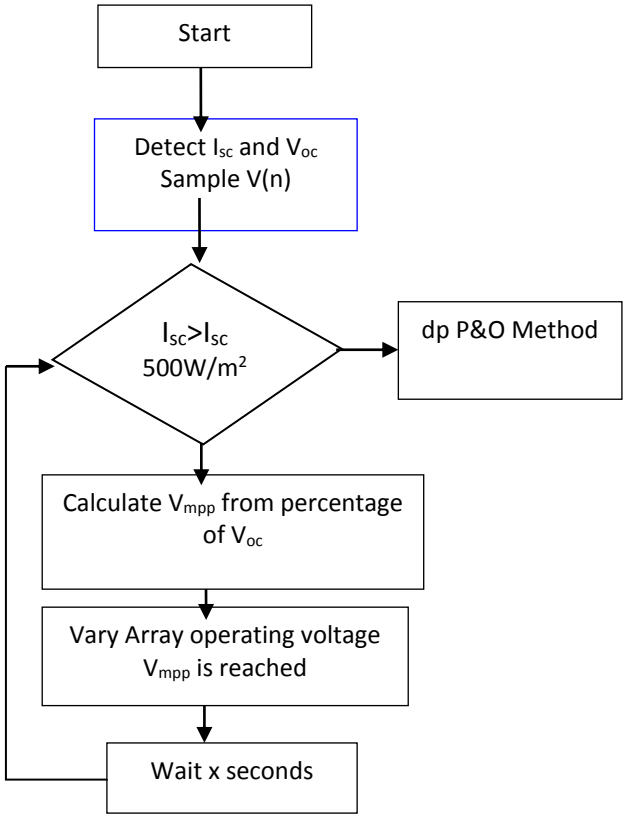

Figure 9 proposed algorithm

V. ACKNOWLEDGEMNT

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