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A Comprehensive Review on MPPT Techniques for PV System

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Abstract: In the current scenario, due to the depleting condition of fossil fuels the world is moving to the renewable energy sources. Solar energy is commonly using renewable energy source because of huge availability. The major issue with the solar system is its low efficiency. Due to the variation in solar radiation and temperature the maximum power point on the PV cell is continuously varying. The maximum power point must be tracked to increase the efficiency of the PV cell. In this paper perturb and observe (P&O), advanced P&O method (3-point P&O algorithm) and incremental conductance(IC) algorithms are compared.

Key words: PV cell, MPPT, Efficiency

1. Introduction:

The continuous use of fossil fuels for power generation causes increase in the carbon dioxide level results in global warming. So the global average temperature level increases. This leads to the use of renewable energy sources for the generation of electricity. The power generation by using renewable energy sources is less compared to conventional methods. Solar energy is the most abundant renewable energy and the electricity generation from sun is increasing day by day. The major problem in generating energy from solar radiation is its dependency on the weather conditions. Energy from the solar radiation is generated by using the Photo voltaic (PV) cell or solar cell. The irregularity in irradiance and temperature results in low efficiency of the PV cells.

By using the maximum power point tracking method the power transfer increases irrespective of the environmental conditions. By considering the I-V and P-V Characteristics of the PV cell the maximum power output point can be tracked [1]. To increase the efficiency of the solar cell the PV system must be operated near the maximum power point. The maximum power point is continuously tracking by a control algorithm to transfer constant maximum power.

2. Photo-Voltaic System:

A photo voltaic system or solar system is designed for the supply of power by using photo voltaic cells. The solar radiation is converted into electricity by the use of semiconductors which exhibit photo voltaic effect.

Modeling of PV system:

The equivalent circuit of a Photo voltaic cell is shown in the fig1. The PV cell is modeled using a current source with small series resistance and a diode is in anti parallel with it [6]. High resistance is connected in parallel to the current source.

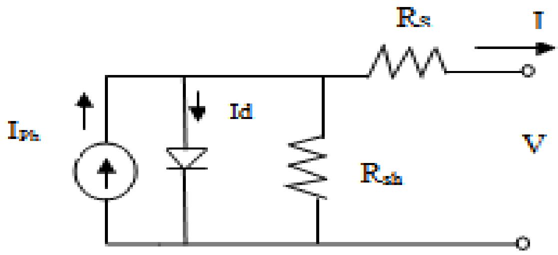

Fig1. Equivalent circuit of a solar cell

Applying Kirchhoff's law:

$$I_{ph} = I_d + I_{rp} + I$$

$$I = I_{ph} - (I_d + I_{rp})$$

The current - voltage relationship of a solar cell can be explained with the following equation:

$$I = I_L - I_0\left(e^{\frac{q(V+IR_S)}{AkT}} - 1\right) - \frac{V+IR_S}{R_{sh}} \quad \ldots\ldots\ldots \quad (1)$$

The output voltage and current of a solar cell are represented by V and I respectively. I_0 Is reverse saturation current, q represents the electron charge. A represents diode ideality factor, k denotes the Boltzmann constant, T is the absolute temperature, R_S and R_{sh} are the series and shunt resistances. R_{sh} is due to the imperfect nature of the P-N junction diode. Equation of the current of a solar cell is derived from the physics of the P-N junction diode and reflects the characteristics of the cell. The photo current of the solar cell is represented by I_{ph} and it is depends on the solar radiation and temperature.

$$I_{ph} = [\, I_{scr} + K_i(T - T_r)\,]S/100$$

I_{scr} is the Photo-voltaic (PV) cell short circuit current at reference temperature and irradiance, K_i is short-circuit current temperature coefficient and S is the solar irradiance. When working temperature of the PV cell increases the output current of the PV module increases, but maximum power output reduces. And total power decreases at high temperatures, because there is a temperature increase around the PV cell there will be decrease in the open circuit voltage. So, efficiency of the cell decreases. The equation 1 is applicable to only a one Photo-Voltaic cell. To get the complete solar panel, the current equation is given as:

$$I = n_p I_L - n_p I_0\left(e^{\frac{q(V+IR_S)}{AkTn_s}} - 1\right) \quad \ldots\ldots\ldots.. \quad (2)$$

Here n_p represent the number of parallel connected solar cells; n_s represent the number of solar cells connected in series. The current-voltage and power-voltage curves of a solar cell are given in fig2.By using the IV curve short-circuit current (I_{sc}), the open-circuit voltage (V_{OC}), the fill factor and the efficiency of the cell can be determined. For low resistances current generated by the solar cell and the short-circuit current are equal and can be interchange.

The open-circuit voltage is the no-load open circuit voltage of the PV cell. At no-load condition when P-N junction diode is forward biased and due to solar irradiance open-circuit voltage is measured. Short-circuit current and the open-circuit voltages are the highest possible current and voltage which can be measured by the given PV model. That is voltage is zero, current is maximum and when current is zero voltage is maximum. The fill factor is defined as the ratio of the maximum power from the solar cell to the product of open-circuit voltage and short-circuits current. The efficiency of solar cell is defined as the ratio of output power from PV cell to the incident solar energy. The efficiency depends on the wavelength, intensity of the solar irradiance and temperature. Under standard conditions the efficiency of a solar cell is calculated by using the following equations:

$$P_{max} = V_{OC} I_{sc} FF \quad \ldots\ldots\ldots\ldots \quad (3)$$

$$\eta = \frac{P_{max}}{P_{in}} \quad \ldots\ldots\ldots\ldots \quad (4)$$

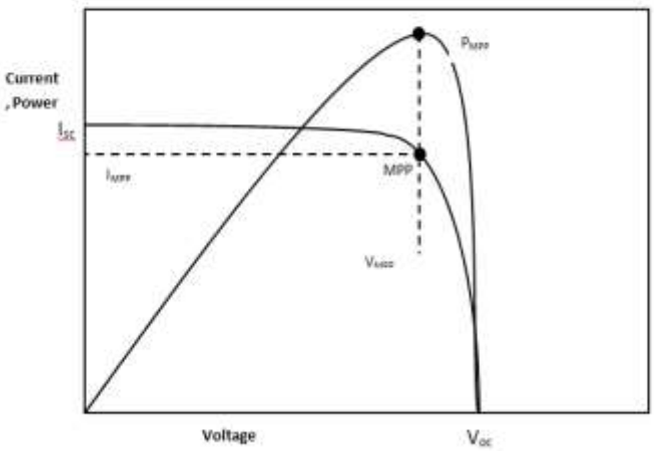

Fig2. I-V and P-V Characteristics of solar cell

3. Maximum Power Point Tracker (MPPT):

To extract the maximum power from the Photo-voltaic cell maximum power point tacking device is used. The Maximum power point is calculated from the knee point of the I-V and P-V characteristics curves. By using the MPPT the voltage level can be balanced between battery and the PV array. MPPT can be tracked by using different algorithm proposed till date.
In this paper 3 methods for the MPPT tracking are discussed and their merits and demerits are provided respectively.

A) PERTURB AND OBSERVE ALGORITHM FOR MPPT:

Perturb and observe algorithm is used to track the MPPT of a PV-model. In this method a slight change in the voltage is provided which is either positive or negative [4]. So the solar panel output power changes according to the voltage change.
If there is an increase in the power then perturbation is increased in small steps. If there is a power decrease then perturbation is reversed. Due to these continuous perturbations the maximum power oscillates. To maintain the power variation to a small value the change in voltage levels must be very small. The flow chart is provided as follows for the Perturb and Observe algorithm technique.

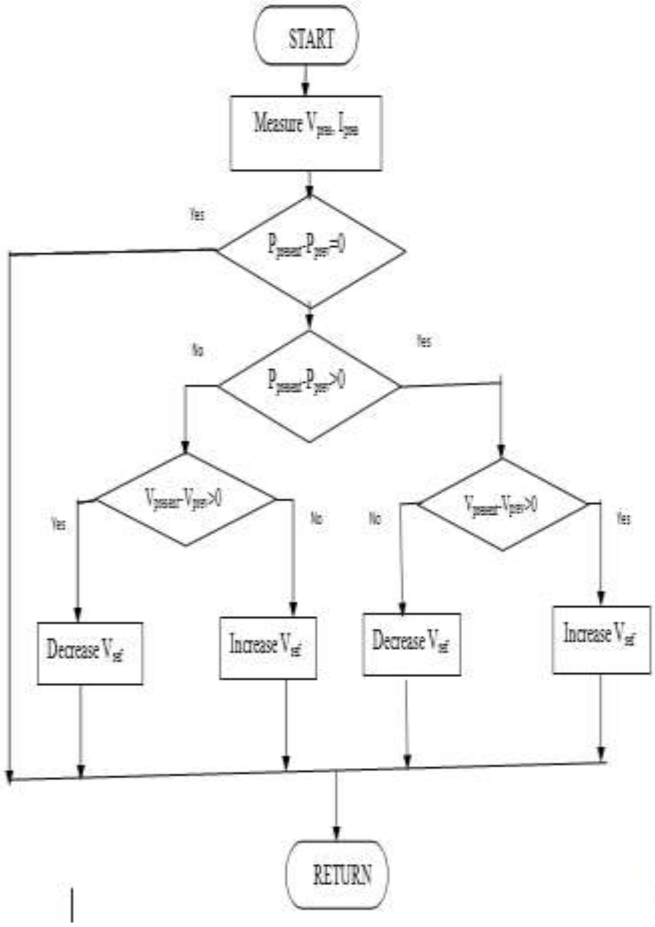

Fig3.P&O algorithm flowchart

In perturb and observe algorithm the reference value of voltage is set to calculate the maximum voltage of the module. The merits and demerits of the algorithm are:
MERITS:

1. Simple structure and operation.
2. When solar radiation is high the Perturb and Observe method gives high efficiency.

DEMERITS:

1. The position of maximum power point tracking is complex at irradiance 400W/m^2.
2. P&O method oscillate around actual MPP.

B) THE 3-POINT P&O METHOD:

The three-point method also known as advanced perturbs and observe control algorithm. In this algorithm three power points on P-V curve of solar model are compared [2]. These three points are “X, Y and Z”. Here “X” is considered as the previous operating point, “Y” is considered as the point that is obtained by increasing the duty cycle by one unit and “Z” is considered as the point obtained by decreasing the duty cycle by one unit.

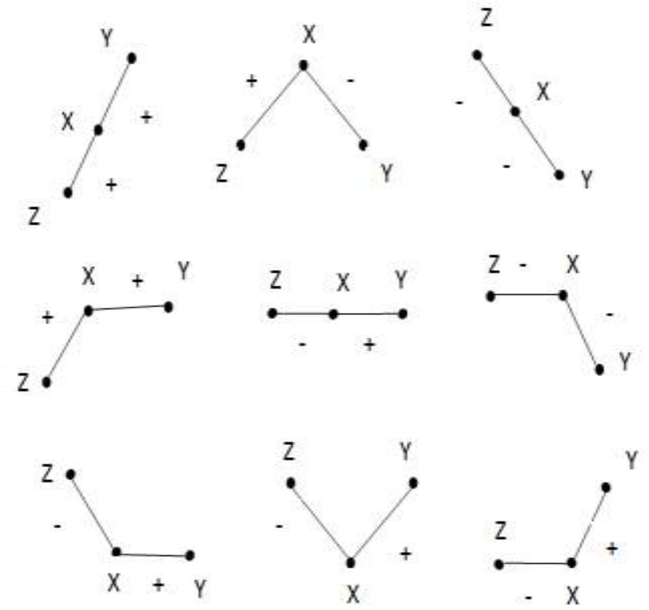

Fig4. 3- point P&O algorithm.

Different states are possible for operating point of maximum power in P-V curves of a designed solar model. The variable "M" (maximum power point) is initialized according to the current operating condition [5].

If the power of point "Y" ≥ "X", then the "M" will be increase by one unit, If the power of point "Y" ≤ "X", then "M" decreases by one unit. Also, if the power of point "Z" ≤"X", then "M" is increased by one unit, otherwise "M" is reduced by one unit.If the value of "M" equals 2, then point "Y" is chosen as the operation point in the next cycle, and if the value "M" equals -2, then point "Z" is chosen as the operation point in the next cycle. In other cases ("M" is equal to 0, 1 or -1), when there is no change in the Maximum power output point there is no need of change in system operating point. so the point "X" is considered as the operating point of PV system. The flowchart of the 3-point P&O algorithm is given in Fig. 5.

MERITS:
The advantages of advance perturb and observe control method are:

1. Low cost.
2. Easy execution.
3. Simple control algorithm.

DEMERITS:
As there is sudden change in solar irradiance and temperature, there will be energy loss.
Three-point method is fails in tracking the MPP of the proposed solar model. The algorithm compares the real power point with the previous values irrespective of the changes in the voltage (positive or negative). At standard temperature and pressure the oscillations around the operating point can be neglected by using the 3-point P&O algorithm.

C) INCREMENTAL CONDUCTANCE ALGORITHM FOR MPPT:

The maximum power can be tracked during rapid changes in solar irradiance by using the Incremental conductance method [3]. In this algorithm method the perturbations or the deviations in the voltage level can be stop once the MPP is reached. The relation between dI/dV and –I/V gives the sign of the perturbations. If dI/dV is negative the MPPT is to the right of the true maximum point. If dI/dV is positive the MPPT is to the left of the true maximum point. By using the incremental conductance method the sudden changes in the solar irradiance can be tracked at a faster rate.

$$P = VI$$

$$(dP/dV)_{max} = d\,(VI)/dV$$

$$0 = I + V dI/dV_{max}$$

$$dI/dV_{max} = \Delta I/\Delta V = -I/V$$

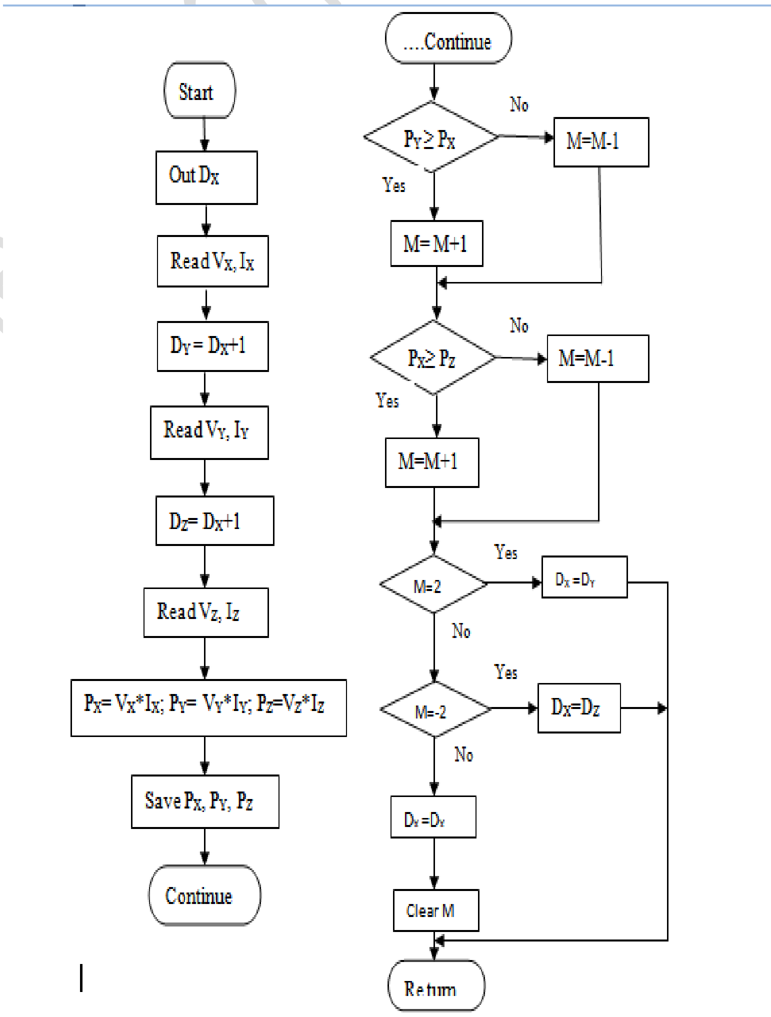

Fig5. 3- point P&O algorithm flowchart.

MERITS:

1. For any rapid change in the solar irradiation the IC method can track the direction efficiently.
2. Power loss is less and efficiency of the system can be improved.

3. MPPT is accurate and fast.

DEMERITS:
1. The system configuration is complex and expensive,
2. Speed control of the system must be provided.

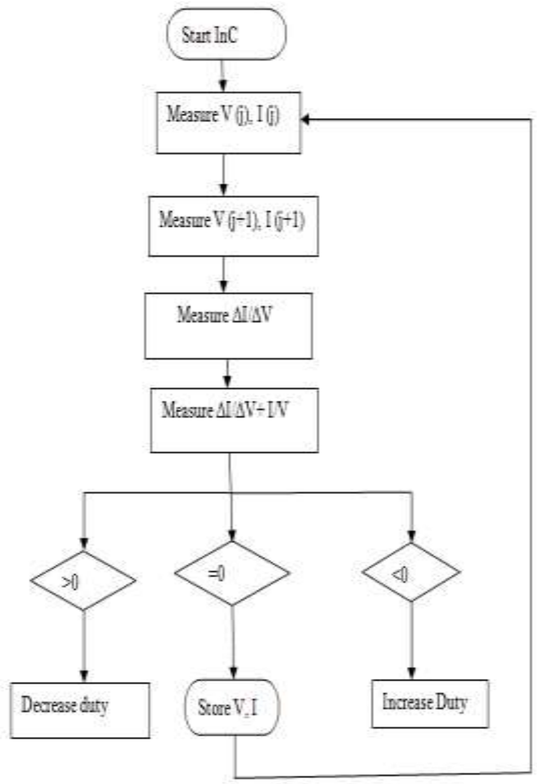

Fig6. Incremental conductance algorithm flowchart

4. Comparison:

Factors	P&O algorithm	3-point P&O algorithm	IC algorithm
Convergence speed	Varies	Varies	Varies
True MPPT	Yes	Yes	Yes
Implementation Complexity	Low	moderate	moderate
PV array dependency	No	No	No
Analog (or) digital	Both	Both	Digital
Measured variables	V/C	V/C	V/C
Periodic tuning	No	No	No

Table1. Comparison of algorithms

5. Conclusion:

Three different algorithms for maximum power point are discussed and compared. They are P&O algorithm, advanced P&O algorithm and Incremental conductance algorithm. The flow charts are provided and merits, demerits of these methods are provided. The comparison of these methods are done based on different parameters known as Maximum power point tracking, complexity, flexibility, efficiency, consistency, availability and etc. The choice of the particular algorithm is decided based on the above factors and environmental conditions such as solar irradiance, temperature, PV model and the location of the solar system.

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