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Maximum Power Point Tracking Techniques for PV Generation: A Review

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Abstract: **This paper provides a literature survey of maximum power point tracking applied to the photovoltaic power system. To maximize the PV array output power MPPT algorithm is used in PV systems irrespective of temperature and irradiation of the weather and electrical characteristics of the load. The load resistance should match the source input resistance to increase the power flow from the photovoltaic systems. This paper presents a comprehensive review of maximum power point tracking techniques with various advantages and drawbacks of each technique are identified for different weather conditions. This manuscript would serve as a convenient reference for future work in maximum power tracking control.**

Keywords: **PV module, maximum power point tracking (MPPT), photovoltaic (PV) power system, DC-DC converter.**

I. INTRODUCTION

Now a day's utilization of photovoltaic power increasing. Solar power is the most efficient and emerging renewable energy source available. Due to rapid development of modern social economy energy demand increases and which causes the environmental crisis such as air pollution. To reduce the dependence on traditional energy we need to develop renewable energy source such as photovoltaic power generation [1]-[5]. Photovoltaic power generated by PV modules and it is mainly based on environmental factors such as various external conditions (light intensity, temperature and load characteristics) and their influence factors, these factors affect the both current-voltage and power-voltage characteristics of the photovoltaic system and hence the connected load and gives the non-linear characteristics. Due to non linear characteristics of the PV systems the maximum power point (MPP) keeps changing accordingly with the solar irradiation levels and cell temperature [6]-[8]. Moreover, the impedance mismatch between solar panel and the load may reduce the output power. PV systems should be designed to operate at their maximum output for any temperature and solar irradiation level which needs a maximum power point tracking algorithms.

II. MAXIMUM POWER POINT TRACKING

The main role of the MPPT controller is to match panel output power with load requirements. MPPT controller ensures that a PV module will produce maximum power for altering weather circumstances and working voltage is maintained at reference voltage. For maximum power transfer between load and PV array at different operating points which is based on the principle of impedance matching between source and load. For a given set of conditions, to match the impedance of a solar array MPPT controller varies the ratio between voltage and current until the operating point provides maximum power. It also ensures a proper charging condition for the batteries and avoids any overcharging and discharging to improve the battery life [9]-[11].

III. MAXIMUM POWER POINT TRACKING TECHNIQUES

Different MPPT techniques have different ways to calculate the V_{mpp} and current at maximum power at which PV array should provide utmost output power P_{mpp} for given irradiance level and temperature conditions [12]. Most of MPP tacking techniques reply to changes in both temperature and irradiance level. But in some methods temperature is assumed to be approximately constant.

A. Hill Climbing / Perturb and Observe Method:

For the reason, that of its straightforwardness and low cost in implementation Perturb & Observe MPPT algorithm is broadly used. P&O compares perturb the operating voltage and power at one point with the previous value [12]-[13]. It keeps on increasing or decreasing the voltage until it reaches the maximum output power where dp/dv=0.

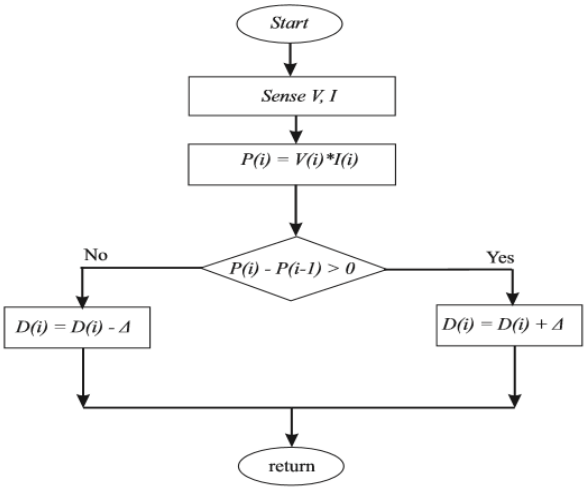

Fig. 1 Algorithm for Hill Climbing

It is observed that when the working point is on left of the MPP is rising in voltage causes increase in power and when the working point is on the right of the MPP is declining in voltage causes reduce in power. It is observed that to reach MPP there is a rise in power consequent perturbation operation should be kept same [14]. Once MPP is achieved, there is reduction in power for next perturbation so perturbation must be inverted. Thus system oscillates about MPP once it is achieved the reduction in step size causes attenuation in oscillations [15].

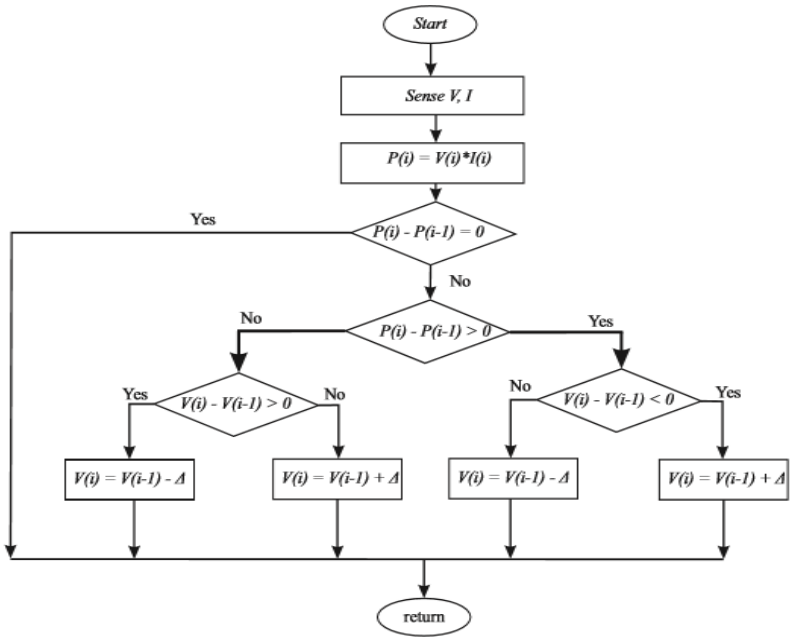

Fig. 2 Algorithm for Perturb and Observation

Advantages:

- The main pro of P&O technique would be simplicity of its structure and ease of implementation.
- High efficiency at a constant and high solar irradiation.

Disadvantages:

- When the solar irradiance drops lower than 400 w/m^2, calculating the precise location of the MPPT becomes extremely rigid and the voltage changes introduced generates small power errors.
- A further problem would be that the real MPP cannot be determined. It can only be oscillated about the required MPP.
- Fast changes in atmospheric circumstances are very unfavourable to functioning of the algorithms it cannot acclimatize to rapid changes in the irradiance and fails to track the MPP in point of fact.

B. Incremental conductance Method:

Under fast changing weather conditions Incremental Conductance (IC) method tracks the peak power unlike P&O method. This method increases or decreases the reference voltage to track the MPP. The algorithm for Perturb and Observe maximum power point tracking is observed in Fig. 3.

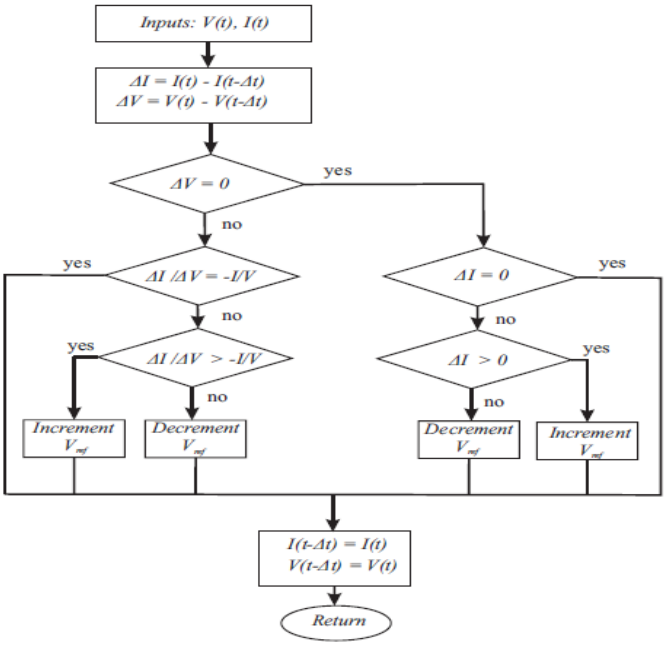

Fig. 3 Incremental Conductance

This method can determine whether the MPPT has reaches MPP and also stops perturbing the operating point. If this condition not met the direction in which the MPPT operating point must be perturbed can be calculated using the relation between $^{dI}/_{dV}$ and$-{}^{I}/_{V}$. The basic equations of this method are as follows.

$$\frac{dI}{dV} = -IV \quad \text{At MPP}$$

$$\frac{dI}{dV} > -IV \quad \text{At Left of MPP}$$

$$\frac{dI}{dV} < -IV \quad \text{At Right of MPP}$$

Advantages:

- Even under rapidly changing conditions IC method does not track in the wrong direction.
- In theory / simulations, even under fast varying atmospheric conditions this method was determined to operate faster, track the power point accurately. Reduce the power loss and improves efficiency.

Disadvantages:

- Incremental Conductance method cost is high and the structure of the system is complex as there is a need for high sampling compliance and speed control.

C. Fractional Open-Circuit Voltage Method:

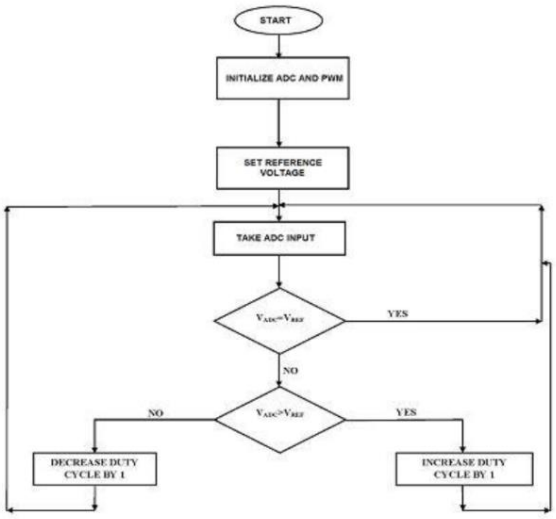

Fig. 4 Fractional Open-Circuit Voltage Method

For changing irradiation levels and temperature values this algorithm is centred on concept of that voltage at which highest power is achieved and open circuit voltage of PV array.

$V_{mpp} \approx P * V_{oc}$

Here P is proportional constant. It is reliant on PV array specification. Range of P is between 0.71 to 0.78.

It is necessary to check V_{oc} periodically. For this power converter should be shut down momentarily. This causes momentary power unavailability. Also, above equation is an approximation so this system by no means operates at the MPP.

Advantages:

- The fractional open-circuit voltage based MPPT utilizes the fact that PV array voltage that corresponding to the maximum exhibits a linear dependence with respect to array open circuit voltage for different irradiation and temperature levels.

Disadvantages:

- The main disadvantage of this method is that PV array as disconnected from the load after regular intervals for the sampling of the array voltage. This results in power loss.
- Another disadvantage is that if the duration between two successive samplings of the array voltage, called sampling period, is too long. There is a considerable loss.

D. Fractional Short-Circuit Current Method:

Under changing atmospheric conditions I_{mpp} is just about correlated to I_{sc} of PV

$I_{mpp} = q * I_{sc}$

Where q is proportional constant. It ranges in between 0.78 to 0.91. it is necessary to measure I_{sc} periodically. This operation is critical as additional switch is required to short of PV array.

E. Fuzzy Logic Control Method:

Fuzzy logic is used to control the system by knowledge based data. FLC is the artificial intelligence technique. Fuzzy logic controller involves in general three platforms namely, fuzzification, rule based table look up and defuzzification. The below Fig. 5 Shows the fundamental block diagram [16].

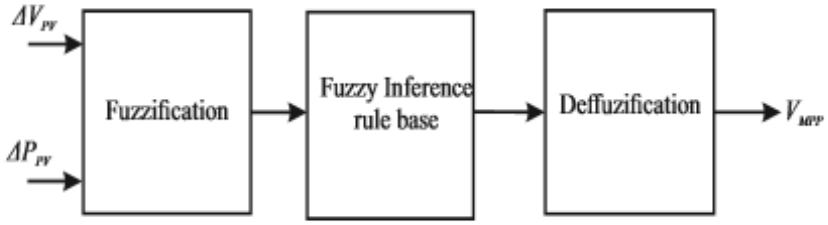

Fig. 5 Block Diagram of FLC

In fuzzy logic controller error (E) and change in error (CE) are the input parameters. Mathematical input parameters are transferred into linguistic variables during the fuzzification which are based on a membership function.

$$E(n) = \frac{p(n) - p(n-1)}{v(n) - v(n-1)}$$

$$CE(n) = E(n) - E(n-1)$$

Fuzzification: The fuzzy procedure requires that each variable used in illustrating the control rules as to specified in terms of fuzzy set scripts with linguistic tags. Five fuzzy sets is assigned as each membership function they are, PH(Positive High), PL(Positive Low), ZC(Zero Close), NL(Negative Low), and NH(Negative High).

Inference method: Fuzzy inference is the procedure of designing the mapping from given input to an output using fuzzy logic in this work, basic rule is applied to obtain a membership function according to Mamdani. The rule table is designed and shown in Table 1.

Table 1: Fuzzy Rule Table

CE	Error				
	NH	NL	ZC	PL	PH
NH	PH	PH	PL	PH	PH
NL	PH	PL	PL	PL	PH
ZC	NL	NL	ZC	PL	PL
PL	NH	NL	NL	NL	NH
PH	MH	NH	NL	NH	NH

Defuzzification: The procedure of defuzzification computes the crisp output of Fuzzy Logic Controller. Most common one is considered, which is centre of gravity defuzzifier.

F. Neural Network Method:

Usually, it is made up of three layers. Namely input layers, hidden layers, and output layers. The number of these nodes in diverse layers is user defined and may change. The input parameter to neural network can be PV panel open circuit voltage and short circuit current, environmental data like irradiation level and ambient temperature [17]. The connection between nodes is weighted. These weights have to be determined through certain process called training process for sharp reorganization of the highest power point. The output results in precise duty signal to power converter.

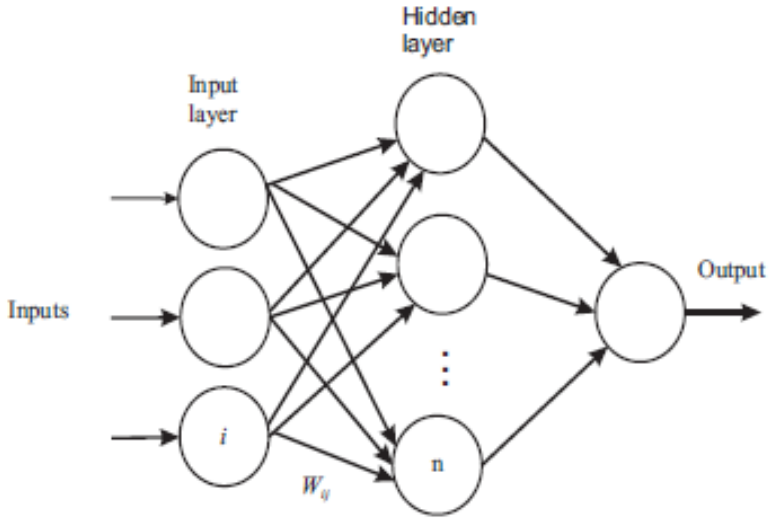

Fig. 6 Basic Diagram of Neural Network

G. Other MPPT Techniques:

- Array Reconfiguration:

This method comprises of different series and parallel combinations of PV arrays. Thus forms reconfiguration of array which results in achieving MPP for certain load, but the real time MPP tracking is not possible.

- Linear current control:

Basis for this technique is the linear relation between i_{mpp} and irradiation level. The current i_{mpp} can be obtained by measuring irradiation level and a PI controller.

- Best Fixed Voltage:

Statistical data of irradiation level as well as ambient temperature is collected for certain time span and MPP corresponding to BFV is found. Control can be done by two ways, either PV array voltage can be set to the BFV or load voltage is considered as reference and output voltage is adjusted accordingly.

- State-based MPPT:

In this technique, system is configured with SSM. Tracking of MPP is achieved by a dynamic feedback controller which is non-linear and time varying. Simulation results say that MPPT is achieved under varying environmental conditions. This technique is robust.

- Slide control method:

Implementation of this method with buck-boost converter is introduced in [18]. $\frac{dp}{d\theta}$ more than zero reflects operation on the left of MPP and $\frac{dp}{d\theta}$ less than zero reflects operation on the right of highest power point. Thus, switching function v is defined.

V=0; S>0

V=1; S<0

Where v=0 shows switch is off and v=1 shows switch is on. This control is configured using microcontroller. This technique senses voltage and current.

Table 2: Comparison between Different MPPT Techniques

MPPT Techniques	Array depended	Analog / Digital	Periodic Tuning	Sensed Parameter	Initial parameter requirement	Convergence speed	complexity	Sensitivity	Ability to track true maxima
PO	No	Both	No	V	No	Varies	Low	Moderate	Yes
INC	Yes	Digital	No	V, I	Yes	Varies	Medium	Moderate	Yes
VOC	Yes	Both	Yes	V	Yes	Medium	Low	Low	No
ISC	Yes	Both	Yes	I	Yes	Medium	Medium	Low	No
RCC	No	Analog	Yes	V, I	No	Fast	Low	Moderate	Yes
PSO	No	Digital	No	V, I	Yes	Fast	Low	High	Yes
FLC	No	Digital	Yes	V, I	Yes	Moderate/Low	High	High	Yes
GA	No	Digital	No	V, I	Yes	Fast	High	High	Yes
Neural Network	No	Digital	Yes	Varies	Yes	Fast	High	Moderate	Yes
ANN	No	Digital	Yes	Varies	Yes	Fast	High	Moderate	Yes

IV. CONCLUSION

Maximum Power Point Techniques (MPPT) controllers are often used to make sure that is to operate in its maximum power point condition of photovoltaic power system. In this literature different MPPT techniques are discussed and analyzed. Focused on various MPPT techniques merits and demerits. Based on literature review, it can be conclude that the conventional MPPT algorithms will provide maximum power output under uniform solar irradiance. But during rapidly changing atmospheric condition these algorithms will fail to provide MPP. This can be resolved by using stochastic and artificial intelligence based MPPT techniques.

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