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A Review on Maximum Power Point Tracking Algorithms for PV System

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Abstract - *Solar or Photovoltaic energy can be considered as the most promising source of renewable energy. A Photovoltaic system converts this solar energy to electrical energy by the use of photovoltaic effect. A photovoltaic system has nonlinear output characteristics and these characteristics keep on changing with respect to temperature and irradiation. So, in order to gather maximum power from the nonlinear output characteristics, many maximum power point tracking algorithms in short MPPT methods have been developed. All these techniques come with their own merits and demerits. This paper attempts to cover a review on five popular MPPT techniques along with the comparison among them. This paper is an attempt in being useful for the researchers to find the suitable MPPT technique which they can put into application.*

Key Words: **FLC, MPPT, P&O, PV System, TPQA**

1. INTRODUCTION

The recent time has seen a paradigm shift in bringing renewable sources of energy into forefront. The global market has been focusing on alternative sources of energy which not only would enhance the quality but also produce sustainable source of energy. The age-old stock of fossil fuel would soon face crisis if alternate source of energy is not put into use.

Can we imagine a world where cars run on solar energy? Well, the idea may sound weird, but since the world is running out of conventional fuels, non-conventional source of energy is the demand of our future time. The use of solar energy or PV systems have now become a popular method of power generation because of its environmental [1] credentials, free energy source, well known technology, lack of maintenance, low cost and increasing efficiency. A PV system has the ability to convert sunlight into electricity directly. But to achieve or extract this solar energy efficiently, we should track the MPP from the PV system's V-I characteristic curve. The MPP keeps changing with the solar irradiation levels and cell temperature. The impedance mismatch between the load and the solar panel may reduce the output power. So, a tracking system is required which would solve this problem of impedance mismatch.

There are several methods developed for tracking the Maximum Power Point under constant and varying weather conditions ranging from simple to complex. This paper is focused at presenting a detailed comparative study of some of the popular MPPT techniques.

2. DIFFERENT MPPT TECHNIQUES

There are numerous techniques of MPPT to improve the energy efficiency of a PV system. A detailed review of different MPPT techniques and some comparison of these techniques are presented below:

2.1 Open- Circuit Voltage Method

It is the simplest and fastest MPPT method. This method assumes a linear relation between the module voltage at the maximum power and module's open circuit voltage. In this method it is considered as the ratio between the Voltage at MPP (V_{MPP}) and the Open circuit voltage (V_{OC}) is almost constant as given in equation (1).

$$V_{MPP} / V_{OC} \cong K < 1 \qquad (1)$$

The whole process of MPPT tracking using this method is described in Fig-1 below:

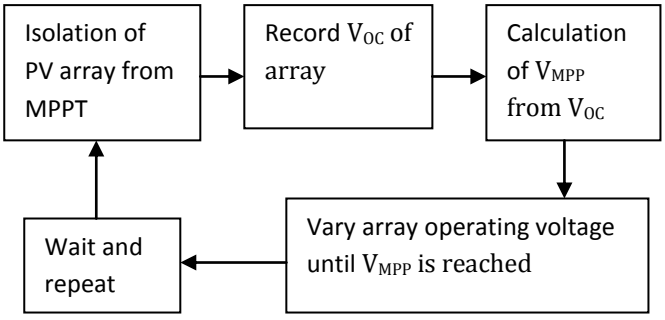

Fig -1: Block diagram of Open-circuit voltage method

As shown in Fig-1, PV module is temporarily isolated by using a switch from the MPPT, and V_{OC} is measured. After that V_{MPP} is calculated according to the linear relationship as in equation (1) and finally the operating voltage is set to that voltage point at which maximum power occurs and periodically this whole process is repeated [3].

The advantage of this method is its simplicity and disadvantage is difficulty to choose the optimal value for constant K. The value of K ranges between 0.73 to 0.80 [**2**].

2.2 Perturb and Observe Method

This is the most common MPPT method as this method is simple and requires a very less no of sensors to measure the parameters. It is an iterative method. After sensing the PV array operating voltage periodically this method compares the present PV System's output power with the previous iteration PV System's output power. If the present output is greater than the previous then the perturbation or next iteration of operating voltage is done in the same direction, on the other hand if it is less, the perturbation is done in the reverse direction. Fig-2 shows the principle of P&O MPPT process and Table-1 covers the summary of P&O method.

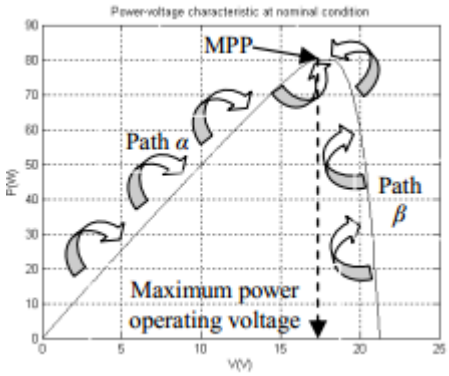

Fig-2 Principle of P&O MPPT process[7]

This method shows some oscillation at Maximum Power Point when the step size taken is large for searching the MPP, which results in loss of an amount of the available power at steady state operation. This occurs more for slow variation in the insulation and temperature constant and this is a disadvantage of this method. Another disadvantage is that the tracking speed of this method becomes very slow if a small perturbation size is taken.

Table -1: Summary of P&O method

Perturbation	Power	Next perturbation
Increase	Increase	Increase
Increase	Decrease	Decrease
Decrease	Increase	Decrease
Decrease	Decrease	Increase

2.3 Enhanced Perturb and Observe Method

Conventional P&O method uses fixed step size for perturbation and has some limitations such as failure under changing environmental condition and oscillation at steady state condition. In order to reduce these types of limitations, an enhanced P&O method is proposed which use variable perturbation depending on PV curve instead of fixed step size used in conventional P&O method.

The variable perturbation step size that relies on power change can be obtained by equation(2) and flow chart in fig-3

$$\Delta Vi = \Delta V0 \times (dPi/dVi) \quad (2)$$

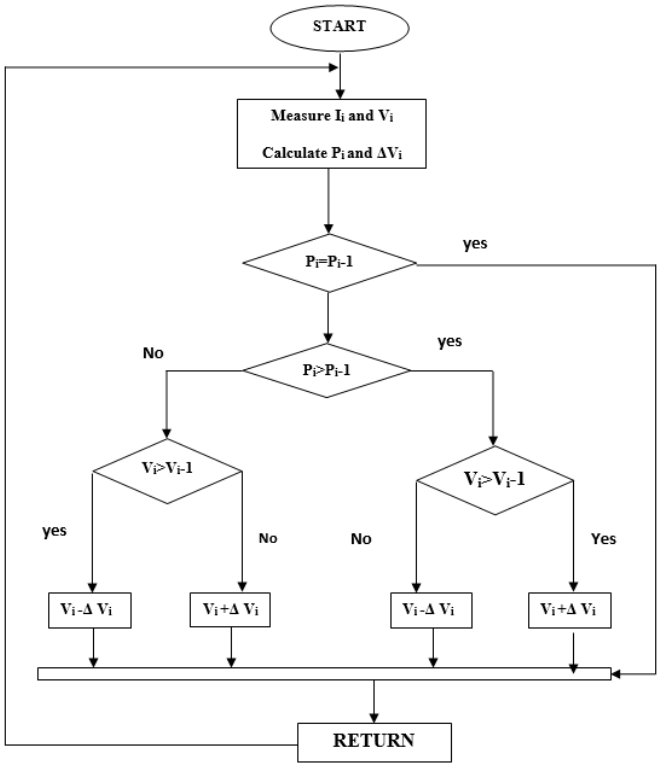

Fig-3 Flow Chart of Enhanced Perturb And Observe Method[4]

2.4 Three Point Quadrature Approach Method

The TPQA algorithm considers the quadratic nature of output power curve of PV system. The algorithm selects three power values such that the point in the middle has the greatest magnitude of all the three power values. If the condition is not satisfied the algorithm shifts the points to the right or to the left depending on the measured values [5]. Then, three quadratic equations are formed which are solved to get approximated peak value:

$$P1 = a.D1\ 2 + b.D1 + C \quad (3)$$
$$P2 = a.D2\ 2 + b.D2 + C \quad (4)$$
$$P3 = a.D3\ 2 + b.D3 + C \quad (5)$$

The process of this method is summarized in the flow chart given in Fig-4

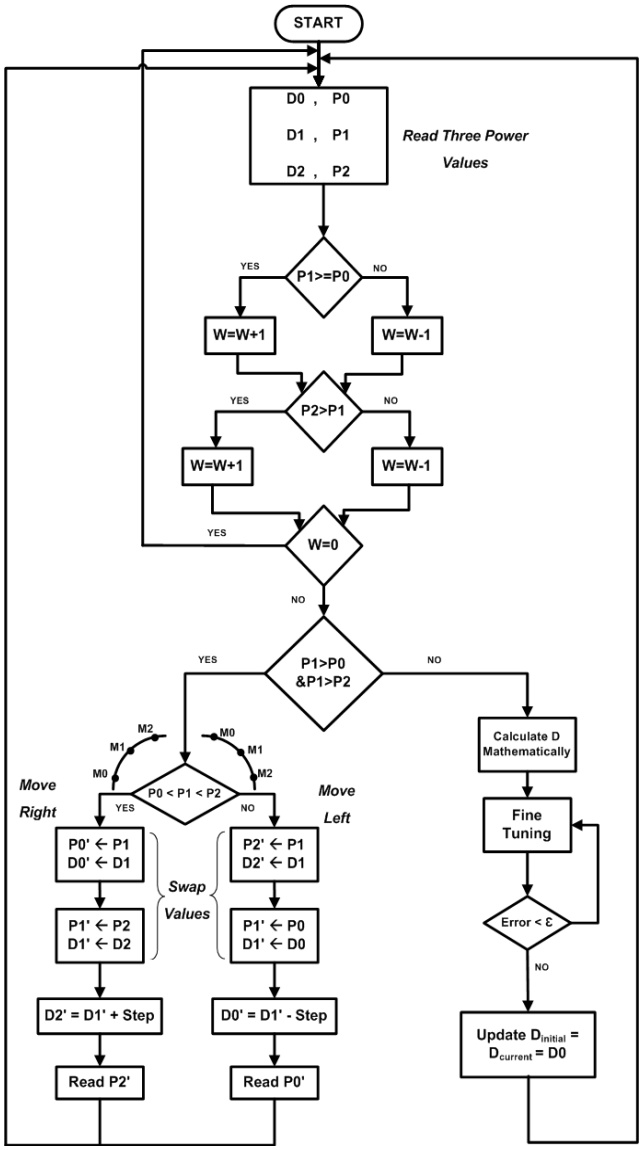

Fig-4 Flow Chart of TPQA algorithm [5]

The main advantage behind this algorithm is that it represents great improvement in the tracking speed compared to the P&O algorithm. The TPQA algorithm uses a large step size during the phase of searching for the three power values and then a very small step size during the fine-tuning stage thus, the algorithm structure insures fast and accurate tracking for the MPP.

2.5 Fuzzy Logic based MPPT Method

We can use fuzzy logic in wide range of fuzzy logic applications. It is a simple process which deals with imprecise inputs and does not demand any accurate mathematical models for analysis. This method can also handle nonlinearities. Fuzzy Logic Control Process can be classified into 3 stages: Fuzzification, rule evaluation and defuzzification. All is described below-

i. Fuzzification: In this first stage of FLC system. It takes a crisp value as the input, for example, the change in the voltage reading in case of MPPT, is taken and is combined with stored membership function for converting it to fuzzy inputs.

ii. Rule evaluation: The second stage in fuzzy logic control is rule evaluation which deals with some linguistic rules to determine what type of control action can be applied in response to a given set of input values. For each consequent action, this step results a corresponding fuzzy output.

iii. Defuzzification: This last stage of FLC is actually the inverse of fuzzification process . This process derives the crisp value expected from an output fuzzy inference variable. The de-fuzzifier effectively transforms all the linguistics output obtained from the fuzzy rule base to corresponding crisp values as outputs.

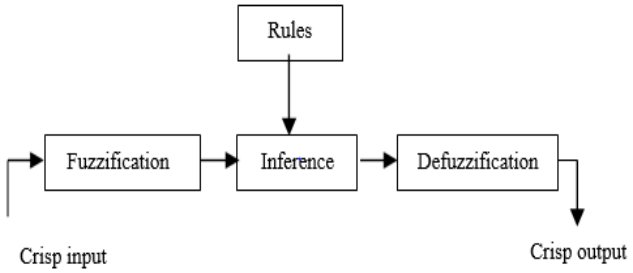

Fig-5 Block diagram of fuzzy logic control [6]

In FLC based MPPT system, the oscillation around the Maximum Power Point is decreased and the response of this method is faster than conventional P&O method.

The proposed inputs of FLC in MPPT are the change or deviation in the PV system's output voltage(ΔV) and change or deviation in the PV system power(ΔP). The output modulation signal from FLC is applied to the PWM circuit to produce the duty cycle pulses to the converter so that the MPP can be reached. Here,

$$\Delta V = V(K) - V(K-1) \quad (6)$$
$$\Delta P = P(K) - P(K-1) \quad (7)$$

This process uses Five fuzzy sets as: NB representing negative big, NS representing negative small, ZE representing zero, PS representing positive small, and PB representing positive big. The design is made in such a way that if the change in voltage causes an increase in output power value, the next change is made in the same direction. Otherwise the voltage change direction is reversed.

Following table presents a rule base used in fuzzy logic controller:

Table-2 A Rule- base used in FLC for MPPT

ΔV \ ΔP	NB	NS	ZE	PS	PB
NB	PB	PS	NB	NS	NS
NS	PS	PS	NB	NS	NS
ZE	NS	NS	NS	PB	PB
PS	NS	PB	PS	NB	PB
PB	NB	NB	PB	PS	PB

3. CONCLUSIONS

The proper and efficient use of solar energy is very necessary to fulfill the energy crisis as well as for solving many environmental issues. Solar energy can not only be one source of alternate energy but also enhance sustainability in a smart way. This paper contains a brief study of the popular MPPT techniques along with some comparison between them. This paper will be helpful for researchers for selecting a proper MPPT technique depending on their field of application.

Over the ages many research works have been executed concerning MPPT techniques. This paper proposes to further outline the disadvantages along with the advantages of these techniques. One of the MPPT method, Constant Voltage Method, has a listed disadvantage that the ratio of MPP voltage to open circuit voltage is approximately constant which leaves scope for further possible improvisation. The second method, i.e. the P&O Method projects some oscillations governing MPP because of its fixed step size which is further reduced in Enhanced P&O method and Three-point quadrature approach algorithm method. However, the Fuzzy Logic Control based MPPT method has significant advantage of having maximum response speed. Keeping this study in consideration, it can be proposed that rather than focusing on one single MPPT technique, more efficient results can be obtained by focusing on hybridization of two or more MPPT techniques as we saw that no single MPPT technique comes with only advantages. Therefore, by deciding to focus on hybridizing two or more techniques the desired result can be achieved. One such example is, during the fine-tuning phase of TPQA method, we can apply the fuzzy based MPPT algorithm to make the response speed faster.

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