PROMINENT MPPT TECHNIQUES FOR PV CELL

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Abstract - *Looking at the world's energy scenario, it is becoming essential to rely on surrogate energy sources. The massive and enormous renewable source is solar energy. This solar energy is considerable alternative for the conventional energy.*

The anemic point of solar energy is the less efficiency in actual use and atmosphere around solar power installation; this is why the point of paper is maximum power point tracking of PV system. The peak power point on the I-V Characteristics of solar cell oscillate continuously due to collection of factors, including alteration in solar radiation, temperature of PV cell, load connected to the PV cell. For magnifying the output of PV cell the peak power point must be regularly tracked. This is the reason that many of solar converters have controller that use MPPT techniques. In this paper various MPPT techniques are discussed.

*Key Words***: PV Cell, MPPT**

1. INTRODUCTION

The demand of world energy are hiking day by day, which is leading to high utilization of fossil fuels, with negative factors impacts on environment like global warming ,acid rain and depletion of ozone layer. It is very hard to overcome the negative impact of fossil fuel, energy technology resulting in ecological stability of the earth. In future hiking in fuel prices and increasing scarcity of fossil fuels may increase economical and political effects on many countries .The possible solution lays in renewable energy system. Recently many energy technology are invaded which are reliable and less cost compared to conventional power generation .The cost of renewable energy is currently falling and further decreases are expected with the increase in demand and production.

Since solar energy is most abundant, the only hurdle is the low efficiency of the solar cell and variation in irradiance due to the weather.

The one suitable track to overcome this low efficiency and variation irradiance affecting power output is the use of a MPPT to track the maximum power point and keep the power transfer at optimum level regardless of the environmental condition.

The characteristics of PV cell are non linear and they have a unique point where output power is maximum. There should be control technique to track the variation in this point so as to deliver constant maximum power.
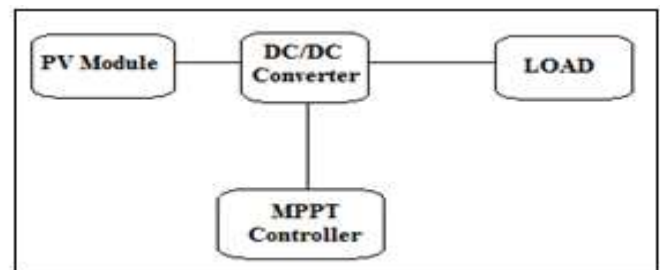

Fig -1: Block diagram of PV System

The PV systems are made of Photovoltaic module, a DC-DC converter, MPPT controller and a load as shown in fig 1.Numerous solar module are connected in series to form the array, and for extracting maximum efficiency MPPT controllers are used.

1.1 PROBLEM OUTLINE

A typical power curve of a PV panel is represented in Fig.2. MPPT technique maintains the voltage (Vmpp) so that highest power (Pmpp) can be achieved for specified isolation level and temperature. Fig. 2 reflects typical I-V curves of PV array for different irradiance levels for fixed cell temperature. As irradiance level increases, current goes on increases.
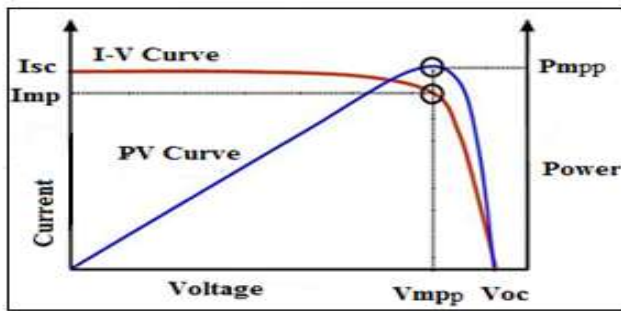
Fig -2: PV Vs IV curve characteristics

Different MPPT techniques have different ways to calculate the (Vmpp) and current at maximum power   (Impp) at which PV array should provide almost output power (Pmpp) ⬚for given isolation level and temperature conditions. Most of MPP tracking techniques reply to changes in both temperature and irradiance level. But in some methods, temperature is assumed to be approximately constant [1].

2. REVIEW OF PROMINENT MPPT TECHNIQUES.

The widely used MPPT techniques are applied for PV applications such as space satellite, solar vehicles, solar water pumping etc. Some succeeding MPPT techniques are discussed below.

2.1 Curve fitting.

The MPP is the extreme value of the PV characteristic of PV panel hence at first the PV characteristics of a PV panel are predicated in this technique [2]. To predict this PV characteristics PV panel can be modeled offline based on mathematical equations or numerical approximation [3], [4]

To achieve an accurate PV curve fitting a third order polynomial function

$$P = aV^3 + bV^2 + cV + \text{d} \qquad (1)$$

Where the coefficients a, b, c and d are determined by sampling of PV voltage and power in intervals differentiation of equation (1) gives

$$\frac{dp}{dv} = 3aV^2 + 2bV + c \qquad (2)$$

At MPP $\frac{dp}{dv} = 0$ (3)

Thus the voltage of MPP can be calculated as

$$V_{mpp} = \frac{-b \pm \sqrt{b^2 - 3ac}}{3a} \qquad (4)$$

In this technique a b c and d are repeatedly sampled in a span of few milliseconds using mathematical equation define in [4] and then V_{MPP} is calculated.

2.2. Perturb and Observe.

The most of the papers concentrate on the Perturb and Observe [5] and [6] methods. As shown in fig. 1, it is observed that increasing voltage causes rise in power when working point is on left of MPP and minimize the power when operating on right of MPP. If it is observed that there is rise in power, consequent perturbation operation should be kept same to attain MPP. 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. [1].The main advantage of this technique is very simple and easily implemented but the disadvantage is the operating point is highly oscillated around the MPP point and not fixed on the exact MPP. The literature review reveals that if we increase the step size the convergence speed will be very less and cannot able to track the MPP at various atmospheric condition several researches in the review suggested or modified the P and O algorithm to have better efficiency compare to the conventional.
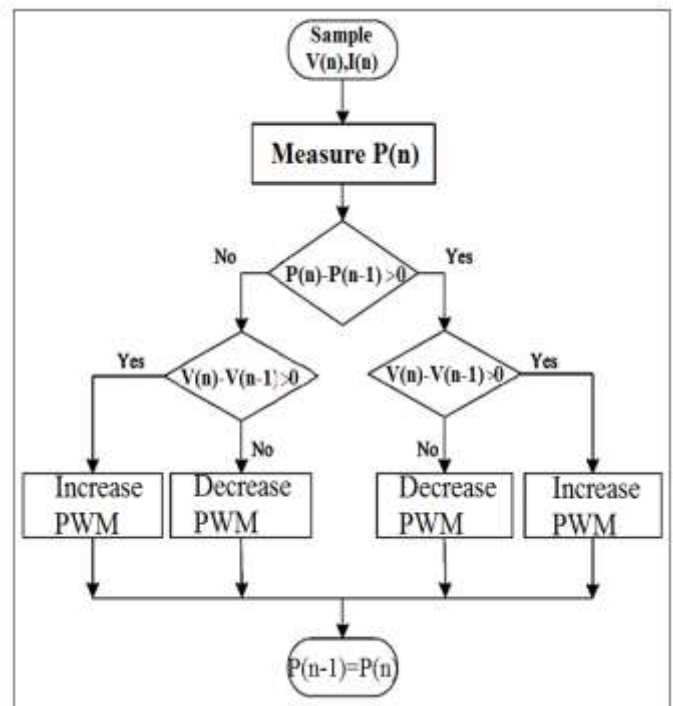

Fig -3: Flowchart of Perturb and Observe Method

2.3 Incremental Conductance.

The IC will verify that the MPPT has reached the MPP and stop perturbing the operating point. If this condition is not satisfy the direction in which the MPPT operating point must be perturbed can be calculated using the relationship

between dl/dV and –I/V This relationship is derived from the very fact that dP/dV is negative when the MPPT is to the right side of the MPP and positive when it is to the left side of the MPP. This algorithm has benefits over P&O in that it can verify once when the MPPT has reached the MPP, where P&O oscillates around the MPP. Also, incremental conductance can track speedily increasing and decreasing irradiance conditions with higher accuracy than P and O [7]
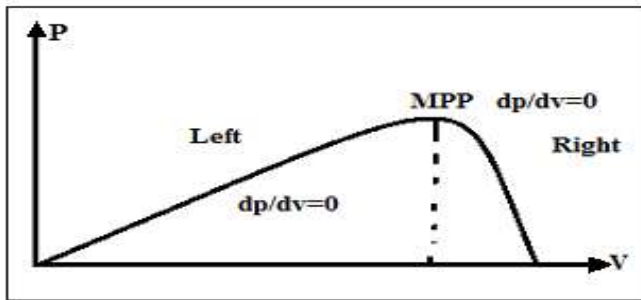

Fig -4: Power vs. Voltage Characteristics

Fig-4 shows that the slope of the P-V array power curve is zero at The MPP, increasing on the left of the MPP and decreasing on the Right hand side of the MPP. The basic equations of this method are as follows. [8]

$$\frac{dI}{dV} = -\frac{I}{V} \qquad \text{At MPP} \qquad (5)$$

$$\frac{dI}{dV} > -\frac{I}{V} \qquad \text{At left of MPP} \qquad (6)$$

$$\frac{dI}{dV} < -\frac{I}{V} \qquad \text{At right of MPP} \qquad (7)$$

This technique gives good result during rapidly changing environment conditions with minimal oscillation but the complex computation procedure of this algorithm makes the implementation very difficult and convergence towards the MPP is not accurate.

2.4. Fractional Short Circuit Current.

To track the power, this MPPT technique requires the value of SCC by isolating the PV array. [9] The MPPT calculated using this technique is based on Equation (8) which is an approximation; hence this method does not operate on true MPPT. The simplicity of this technique makes it easy for use in small scale cheap applications. This method is suitable to be implemented by using either the analog or the digital mode. The basic outline of this technique follows that the current at MPP (Impp) is closely located near the short circuit current Isc. Therefore, the operating point can be reached by multiplying Isc by the factor k as given below:

$$\text{Impp} \approx k \, \text{Isc} \qquad (8)$$

The constant "k" can be easily calculated from the specifications of the PV module and it is always less than 1.

The constant k is a fixed value and therefore, can be used as a fixed entity in the algorithm. Typically the value of k is in between 0.85 and 0.95. [10] FSCC MPPT needs only a current sensor and therefore it is less expensive and easy to implement. The disadvantage includes the periodic loss of power in measuring the short circuit current.

2.5. Fuzzy Logic Control.

Fuzzification comprises the process of transforming numerical crisp inputs into linguistic variables supported the degree of membership to certain sets. Membership functions, like the ones in Figure 6, are used to associate a grade to each linguistic term. The number of membership functions used depends on the accuracy of the controller, but it usually varies between 5 and 7 [11], [13]-[14].
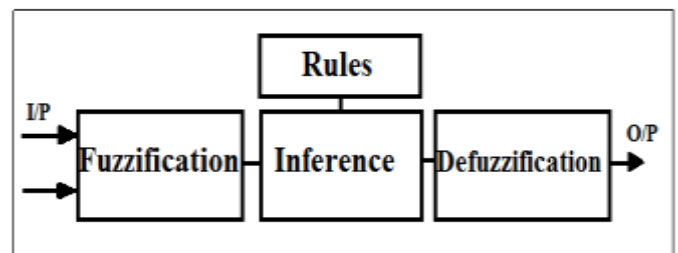

Fig 5: Block diagram of fuzzy logic control

In Figure 6 seven29fuzzy levels are used: NB (Negative Big), NM (Negative Medium), NS (Negative Small), ZE (Zero), PS (Positive Small), PM (Positive Medium) and PB (Positive Big).The values a, b and c are based on the range values of the numerical variable. In some cases the membership functions are chosen less symmetric or even optimized for the application for better accuracy [11], [14].NB NM NS ZE PS PM PB

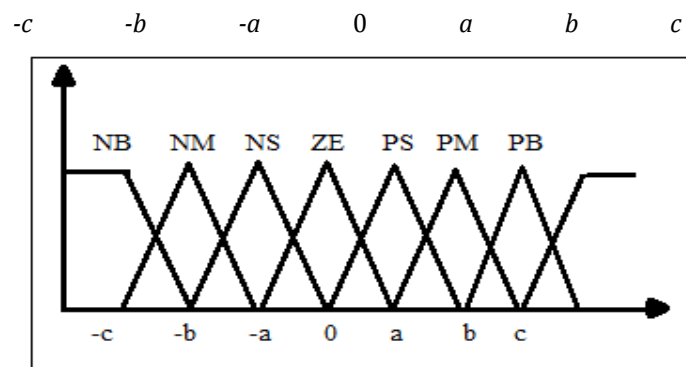-c   -b   -a   0   a   b   c

Fig 6: Membership functions

The inputs of the fuzzy controller are usually an error E, and the change in the error,ΔE. The error can be chosen by the

designer, but usually it is chosen as $\Delta P/\Delta V$ because it is zero at the MPP. Then E and ΔE are defined as follows:

$$E = \frac{P(K)-P(K-1)}{V(K)-V(K-1)} \tag{9}$$

$$\Delta E = E(K) - E(K - 1) \tag{10}$$

In another cases $\Delta P/\Delta I$ is employed as error [13] or other inputs are considered, as in [14]. Where ΔU and ΔP are used. The output of the fuzzy logic converter is usually a change in the duty ratio of the power converter, ΔD, or a change in the reference voltage of the DC-link, ΔV. The rule base or fuzzy rule algorithm, associates the fuzzy output to the fuzzy inputs based on the power converter used and on the knowledge of the user. Table I shows the rules for a three phase inverter, where the inputs are E and ΔE, as defined in (9) and (10), and the output is a change in the DC-link voltage, ΔV. For example, if the operating point is far to the right side of the MPP, E is NB, and ΔE is zero 30then to reach the MPP the reference voltage should decrease, so ΔV should be NB(Negative) to move the operating point towards the MPP.

Defuzzification is the last stage. In this stage the output is converted from a linguistic variable to a numerical crisp one again using membership functions as those in Figure 6. There are number of methods to transform the linguistic variables into crisp values. It can be said that the most famous is the center of gravity method. The benefits of these controllers are dealing with imprecise inputs and no need of an accurate mathematical model and handling nonlinearity, are fast convergence and minimal oscillations around the MPP. Next, they have been shown to perform well under step changes in the irradiation. However, no proofs were found that they perform well under irradiation ramps. Therefore, their performance under the conditions specified in [12] for testing the dynamic MPPT efficiency is unknown. Another disadvantage is that their effectiveness depends a lot on the skills of the designer; not only on choosing the right error computation, but also in coming up with an appropriate rule base [11].

6. Artificial Neural Networks

Artificial Neural Network (ANN) is an artificial network that mimics the human biological neural networks behavior, widely used in modeling complex relationships between inputs and outputs in nonlinear systems. ANN can be defined as parallel distributed information processing structure consisting of inputs, and at least one hidden layer and one output layer. These layers have processing elements called neurons interconnected together as shown in fig 7.

An ANN is developed, such that the current solar irradiance and temperature are its inputs and the voltage, which corresponds to maximum power output of the array The first step in designing an ANN is to collect historical data on the problem that is being solved using the network. In case of MPPT lots of array solar irradiances and temperatures and their corresponding maximum power point voltages are required to in order to train the network. This obtained data is called (training points). The input information is connected to the hidden layers through weighted connections where the output data is calculated. The number of hidden layers and the number of neurons in each layer controls the performance of the network.
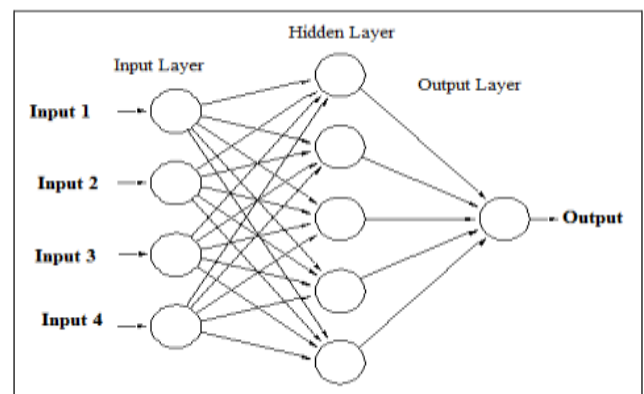

Fig 7: General structure of 4 inputs ANN

Benefits of ANN, it learns and does not need to be reprogrammed and if any element fails it can continue without any problem by their parallel nature.

Comparison:

The main objective of all the techniques is to maximize the PV output power. In this paper the following points are discussed mainly the convergence speeds, Algorithm complexity, PV array dependency tracking accuracy, hardware implementation and its applications. The table shows the applications. The table shows the comparison of main MPPT technique

A. Tracking and convergence Speed

According to the climatic condition the solar irradiation is not uniform so partial shading takes place due to this PV characteristics will have multiple peaks formation which leads to immediately affect the following efficiency and convergence speed of the PV system. The P&O and INC algorithms cannot track MPP in one steps, it requires iterative steps to sense and calculate and perturb, so the

tracking is slow, in comparison fuzzy ,ANN based MPPT algorithm are very sensitive and have highest capability to track the global peak at very high speed irrespective of the environmental conditions.

B. Algorithm complexity.

The efficiency of MPPT depends on the algorithm ,calculation done in the algorithm design of algorithm .To extract the maximum power accurate algorithm should be design open circuit and short circuit algorithm should be design, open circuit and short circuit algorithm are very simple ,fast and not much calculation required on the other hand in fuzzy logic and ANN have highly complex algorithm design .It has the advantages of working with imprecise inputs ,not requiring accurate mathematical model and handling non linearity.

C. Implementation.

While designing the PV system implementation of the MPPT techniques is also an important Fuzzy logic and ANN is soft computing intelligence algorithm it requires sound knowledge of programming and software.

D. Costs.

The cost of the PV system depends on the circuit and hardware used as the sensors are included in digital circuits which increased the cost; hence choice of digital circuit is high compared to analog and circuit.

E.Applications

The discussed MPPT techniques are used for different application. The precise MPPT is required for the space satellites and communication system. The algorithm complexity and cost do not matter, the only purpose is to track precise and optimum, so P&O and INC are useful for designing the solar vehicles it requires high convergence speed to the MPP to be very fast so fuzzy logic and ANN are suitable for street light easy and cheap implementation is required then open circuit.

3. CONCLUSION

This paper reviews the various MPPT techniques, which is used in photovoltaic system. The technical aspects merits, demerits are studied. In this review it is concluded that all techniques are suited for various applications as the technique changes respective to uniform solar irradiation for better and precise output, MPPT based on artificial intelligence which exhibits good performance in tracking the MPP ,still researches are going on for finding simple , low cost and highly efficient technique.

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