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Various MPPT Techniques for Solar PV Module- A Survey & Analysis

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Abstract

Electricity demand is growing with highest rate for the energy consumed worldwide. Thus the mankind is facing a massive challenge of never ending increase in energy demand. Availability of solar energy has an exceptional potential to make a noteworthy involvement to the world's energy requirement. As solar panels are used in a normal conventional way, its non linear property in current and voltage and power- voltage characteristic increases. These characteristics may reduce the efficiency of solar panel. Hence for increasing efficiency and reducing effect of non-linearity of characteristics it requires Maximum power point tracking technique for controlling the solar panels. Hence the aim of MPPT is to control the voltage of solar panels in the influence of variation in atmospheric conditions. Recently lots of researchers making efforts to enhance the power output of the module in terms of maximum power point tracking (MPPT). It is an important part to analyze and formation of solar power projects. In this work, a deep review of different MPPT techniques analysis and discussion is presented for solar PV system. Further the use of an efficient method to get lower disturbance and higher energy has been explained.

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Index Terms: *MPPT, Renewable energy sources, MPPT Algorithm*

1.INTRODUCTION

The photovoltaic (PV power generation has shown a significant potential in fulfilling the growing world's energy demand. Uptotheyear2011, global operation of solar power generation has risen upto70GWp, inwhichalmost30GWp solar power came into the marketin2011 [1,2]. Inyear2012, the total PV operating capacity has increased to100GWp [3]. Solar energy has gained much popularity as it is a form of renewable energy with many advantages.

Renewable energy is the energy which comes from natural resources such as sunlight, wind, rain, tides and geothermal heat. These resources are renewable and can be naturally replenished. Therefore, for all practical purposes, these resources can be considered to be inexhaustible, unlike dwindling conventional fossil fuels [4]. The global energy crunch has provided a renewed Impetus to the growth and development of Clean and Renewable Energy sources. Clean Development Mechanisms (CDMs) [5] are being adopted by organizations all across the globe.

1.1. Maximum Power Point Tracking

Maximum power point tracking (MPPT [6, 7], is a technique used commonly with wind turbines and photovoltaic (PV) solar systems to maximize power extraction under all conditions. PV solar systems exist in many different configurations with regard to their relationship to inverter systems, external grids, battery banks, or other electrical loads.[3] Regardless of the ultimate destination of the solar power, though, the central problem addressed by MPPT is that the efficiency of power transfer from the solar cell depends on both the amount of sunlight falling on the solar panels and the electrical characteristics of the load.

As the amount of sunlight varies, the load characteristic that gives the highest power transfer efficiency changes, so that the efficiency of the system is optimized when the load characteristic changes to keep the power transfer at highest efficiency. This load characteristic is called the maximum power point and MPPT is the process of finding this point and keeping the load characteristic there. Electrical circuits can be designed to present arbitrary loads to the photovoltaic cells and then convert the voltage, current, or frequency to suit other devices or systems, and MPPT solves the problem of choosing the best load to be presented to the cells in order to get the most usable power out. Solar cells have a complex relationship between temperature and total resistance that produces a non-linear output efficiency which can be analyzed based on the I-V curve [8,9]. It is the purpose of the MPPT system to sample the output of the PV cells and apply the proper resistance (load) to obtain maximum power for any given environmental conditions.

MPPT devices are typically integrated into an electric power converter system that provides voltage or current

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conversion, filtering, and regulation for driving various loads, including power grids, batteries, or motors.

- Solar inverters convert the DC power to AC power and may incorporate MPPT: such inverters sample the output power (I-V curve) from the solar modules and apply the proper resistance (load) so as to obtain maximum power.
- The power at the MPP (Pmpp) is the product of the MPP voltage (Vmpp) and MPP current (Impp).

1.2. MPPT Implementation

When a load is directly connected to the solar panel, the operating point of the panel will rarely be at peak power. The impedance seen by the panel derives the operating point of the solar panel. Thus by varying the impedance seen by the panel, the operating point can be moved towards peak power point. Since panels are DC devices, DC-DC converters must be utilized to transform the impedance of one circuit (source) to the other circuit (load). Changing the duty ratio of the DC-DC converter results in an impedance change as seen by the panel. At a particular impedance (or duty ratio) the operating point will be at the peak power transfer point. The I-V curve of the panel can vary considerably with variation in atmospheric conditions such as radiance and temperature. Therefore it is not feasible to fix the duty ratio with such dynamically changing operating conditions. MPPT implementations utilize algorithms that frequently sample panel voltages and currents, then adjust the duty ratio as needed. Microcontrollers are employed to implement the algorithms. Modern implementations often utilize larger computers for analytics and load for casting.

1.3. MPPT Techniques

There are many MPPT methods available in the literature [1]-[14]; the most widely-used techniques are described in the following sections:

- Constant Voltage (CV) Method
- Open Voltage (OV) Method
- Temperature Methods
- Incremental Conductance (IC) Methods
- Perturb and Observe (P&Oa and P&Ob) Methods
- Three Point Weight Comparison
- Short-Current Pulse Method
- Fuzzy Logic Method
- Sliding Mode Method
- Artificial neural network Method

2. Literature Review

Studies show that a solar panel converts 30-40% of energy incident on it to electrical energy. A Maximum Power Point Tracking algorithm is necessary to increase the efficiency of the solar panel. There are different techniques for MPPT such as Perturb and Observe (hill climbing method), Incremental conductance, Fractional Short Circuit Current, Fractional Open Circuit Voltage, Fuzzy Control, Neural Network Control etc. Among all the methods Perturb and observe (P&O) and Incremental conductance are most commonly used because of their simple implementation, lesser time to track the MPP and several other economic reasons.

Under abruptly changing weather conditions (irradiance level) as MPP changes continuously, P&O takes it as a change in MPP due to perturbation rather than that of irradiance and sometimes ends up in calculating wrong MPP[10]. However this problem gets avoided in Incremental Conductance method as the algorithm takes two samples of voltage and current to calculate MPP. However, instead of higher efficiency the complexity of the algorithm is very high compared to the previous one and hence the cost of implementation increases. So we have to mitigate with a trade off between complexity and efficiency.

It is seen that the efficiency of the system also depends upon the converter. Typically it is maximum for a buck topology, then for buck-boost topology and minimum for a boost topology. When multiple solar modules are connected in parallel, another analog technique TEODI is also very effective which operates on the principle of equalization of output operating points in correspondence to force displacement of input operating points of the identical operating system. It is very simple to implement and has high efficiency both under stationary and time varying atmospheric conditions [11].

3. Photovoltaic Cell And Mpp

Figure1 shows the equivalent circuit of solar cell. Electrical energy production of cell has been symbolized by current (Iph) demanded from voltage-dependent current source. The amount of produced energy is proportional to solar radiation. Because the body of the solar cell semiconductor material is symbolized as a diode, output voltage of PV cell is shown as Vpv.

Serial resistance (Rs) is equal to the sum of contact and semiconductor material's resistances. Parallel resistance (Rp) is taken as the sum of resistances between thin-film layers and around cells. In the investigations, it is determined that parallel resistance is too large compared with series resistance, and its effect can be neglected.

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As shown in Figure 1, output current of an SC is equal to difference short circuit (ISC) current and diode current (ID).

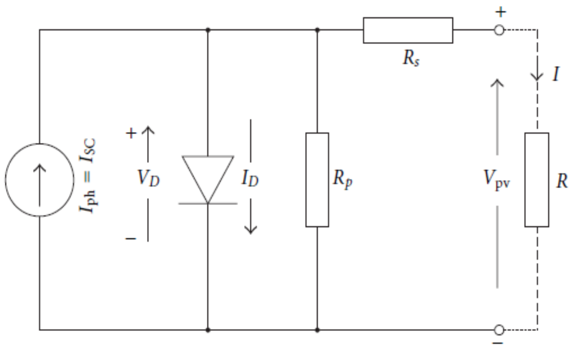

Fig. 1 Equivalent electrical circuit of an SC [12].

In this case, following equation can be written as

$$I = I_{ph} - I_D = I_{ph} - I_0\left(e^{(q\cdot V)/(k\cdot T_C)} - 1\right). \quad (1)$$

where k, TC, q, V, and I0 show the Boltzmann gas constant [k = 1.38 × 10−23(j/K)], absolute temperature of SC [K], electron charge [1.6 × 10−19C], voltage across the cell, and the dark saturation current that varies greatly depending on the temperature, respectively. In (1), if the output current assumed as zero, open circuit voltage (VOC) is determined as

$$V_{OC} = \frac{k\cdot T_C}{q}\ln\frac{I_{ph}+I_0}{I_0} \approx \frac{k\cdot T_C}{q}\ln\frac{I_{ph}}{I_0}, \quad (2)$$

In Figure 2, current-voltage (I-V) and power-voltage (P-V) characteristics of a typical SC under variable solar radiation conditions are shown. As understood from current voltage characteristic, when SC is illuminated, a positive potential occurs at the ends of SC, and an output current can be produced. If a variable resistance (R) is connected as load to the SC Otherwise, when R value is too high, SC will operate between E-F points as a constant voltage source. The most efficient operation point of cell is (A) and called as maximum power point (MPP).

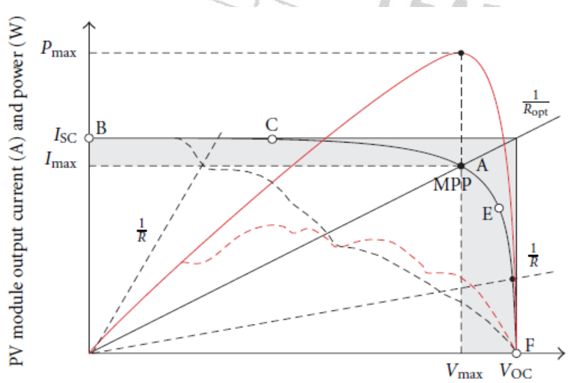

Figure 2: Characteristics of a typical PV cell [12].

Output power (Pmax) and efficiency (ηmax) values at this point are equal to

$$P_{max} = I_{max} \cdot V_{max},$$

$$\eta_{max} = P_{max}/P_{in} = P_{max}/A \cdot G_a \quad (3)$$

In these equations, A and Ga represent photovoltaic array area [m2] and ambient solar radiation inW/m2, respectively. Another criterion of I-V characteristic is fill factor (FF). FF will also determine the quality of SC. In PV system design, FF value of used SC must be 0.7 or greater. Mathematically, FF can be expressed by the following equation [12].

$$FF = \frac{P_{max}}{|V_{OC}\cdot I_{SC}} = \frac{V_{max}\cdot I_{max}}{V_{OC}\cdot I_{SC}}. \quad (4)$$

MPP, where SC output power reached the maximum value, varies depending on the angle of sunlight on the surface of the panel and cell temperature. Hence, the operating point of the load is not always MPP of PV. Therefore, in order to supply reliable energy to the load, PV systems are designed to include more than required number of modules. In this case, the system cost and the amount of energy loses greatly increase. The solution to this problem is that switching power converters can be used that is called as maximum power point tracker (MPPT).

4. Classification of MPPT algorithm

The aim of MPPT is to regulate the actual operation voltage of PV panel to the voltage at MPP. For this purpose, MPPT adjusts the output power of inverter or DC converter. If the PV output voltage is higher than MPP voltage, then transferred power to the load or network is increased, otherwise, it is decreased [13].

4.1. Indirect MPPT Algorithms

Indirect MPPT algorithms operate based on calculation of PV cell voltage at maximum power point using sample measurements and assumptions. There are several application modes of these techniques, and some of them are summarized below.

(i) System voltage (operating voltage of PV panel) can be adjusted seasonally. In this case, depending on cell temperature, it is expected that MPP voltage in winter will be higher than summer.

(ii) Operating voltage can be adjusted according to the temperature of the module.

(iii) MPP voltage can be calculated by multiplying of instantaneous open-circuit voltage of PV cell with a certain constant coefficient (such as, for example, 0.8 for silicon cells). Open-circuit voltage is measured periodically. These measurements are realized by interruption of load for very short times such as 1ms every two minutes.

(iv) In some systems, MPPT algorithms are designed according to the azimuth and altitude of the sun. Depending on geographical location of PV system, the change of angle of the sun is transferred to a database. Thus, MPPT movements are formed by information in this database as in [14].

4.2 Direct MPPT Algorithms

In these MPPT algorithms, optimal operating point is determined by measurement of PV panel current, voltage, or power. Therefore, these methods affected the performance changes in time due to various reasons and can make a more accurate tracking.

4.3 Perturb and Observe (P&O) Algorithm

P&Q is the most widely used algorithm due to the simplicity of implementation practically. In this method, P-V characteristic of PV cell is used. As known, produced power by PV array varies as a function of voltage. In P&O algorithm, a small increase in operating voltage of PV array is realized, and the amount of change in power (ΔP) is measured. If ΔP-value is positive, operating voltage is increased again to reach MPP, thus, sign of power error track by these small voltage errors.
The main advantages of P&O algorithm are simple structure and ease of implementation, with both stand-alone and grid-connected systems, MPP tracking can be done with very high efficiency.

4.4 Artificial Intelligence-Based MPPT Algorithms

In recent years, fuzzy logic (FL), artificial neural networks (ANNs), and genetic algorithm (GA) techniques known as artificial process. Especially under non uniform and partially shading conditions, power and current characteristics of PV cells are more complex, and it is also more difficult to track MPP. Therefore, for a satisfactory result, all environmental conditions (especially instantaneous climate changes and partially shading) must be taken into account in the design process of MPPT. Artificial intelligence can produce appropriate solutions for these conditions. Intelligence techniques have been used widely in the MPPT.

4.5 Constant Voltage (or Current) Algorithms

Constant voltage (CV) algorithm is based on approximately constant ration between voltage of MPP (Vmax) and open-circuit voltage as given in the following equation:

$$V_{max}/V_{OC} \sim= K < 1. \quad (5)$$

In this algorithm, solar panel is temporarily separated from MPPT, and open-circuit voltage is measured. Later, voltage at MPP is calculated by using (5). By the adjusting of array voltage to this calculated value, the operation at MPP is achieved. This process is repeated periodically and the position of MPP is tracked continuously. Although this method is quite simple, it is difficult to determine the optimal value of constant K.

4.6 Incremental Conductance Algorithm

Incremental conductance (IC) algorithm is based on that the derivative of PV power by the voltage is equal to zero. Accordingly, at the maximum power point,

$$dP/dV = d(V \cdot I)/dV = I + VdI/dV = 0 \qquad (6)$$

IC method as different from P&O algorithm can determine in which direction it has to do voltage changing. Therefore, IC method does not track in the wrong direction even under rapidly changing conditions. In addition, this method can also calculate reached or not to MPPT exactly.

4.7 Parasitic Capacity Algorithm.

Parasitic capacity (PC) method shows similarities with the IC method. However, changing of parasitic junction capacity (PJC) value is taken into account in this method. PJC occurs as result of charge accumulation in p−n junction area and the inductance associated to the connections of PV cells. Actually, there are two main components (parasitic capacitance and inductance) called the reactive parasitic components. It is determined that the parasitic capacitance reduces the error signal when the PV panel is operating outside the MPP, slowing down the system dynamic. But these unavoidable losses are used as an important parameter in determining the MPP.

5. Conclusions

MPPT algorithms used in PV systems are one of the most important factors affecting the electrical efficiency of system. As a result of cost optimization, after decided to use an MPPT system by the designer, it is important to decide which algorithm will be used in application. In this study, a small review of general classification and descriptions of the most widely used MPPT algorithms are analyzed in detail. Operating principles and application processes of MPPT algorithms such as perturb and observe, constant voltage and current, incremental conductance, parasitic capacity, three point weight comparison, and artificial intelligence have been discussed.

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