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Review article

Comparative assessment of maximum power point tracking procedures for photovoltaic systems

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Abstract

The fast growing demands and increasing awareness for the environment, PV systems are being rapidly installed for numerous applications. However, one of the important challenges in utilizing a PV source is the maximum power harnessing using various maximum power point tracking techniques available. With the large number of MPPT techniques, each having some merits and demerits, confusion is always there for their proper selection. Discussion on various proposed procedures for maximum power point tracking of photovoltaic array has been done. Based on different parameters analysis of MPPT techniques is carried out. This assessment will serve as a suitable reference for selection, understanding different ways and means of MPPT.

Keywords: Maximum power point tracking (MPPT); Photovoltaic (PV); Solar; Perturb and observe; Optimization

1. Introduction

With the recent progress in technology, government schemes and the development of a healthy mind set, a shift towards use of renewable energy sources has been observed. Due to improvement in PV array manufacturing, efficiency and the fickle fuel costs, the use of PV system is gaining rapid momentum. And by the increase in the usage of renewable energy systems like solar PV and wind systems, development of technology for maximum power extraction from these systems is a must.

The maximum power point on highly nonlinear V—P characteristic of PV array depends on the atmospheric conditions [1—4]. Also the operating power point on the V—P characteristics depends on the impedance of connected load [1,5—7]. To extract maximum power from PV array various MPPT methods are used. These MPPT methods compel the PV array to operate at or very close to the maximum power point of the V—P or I—V characteristic [5—7]. The algorithms that are used in maximum power point trackers dynamically bring the current or voltage at or near the maximum power point.

Till date, a large number of MPPT methods have been proposed and developed. Some of these methods are for general purpose application and some deals with specific application. They may involve DC—DC converter or DC—AC converters with direct or hybrid algorithms. This script phases out through a wide range of approaches used for MPPT with a brief discussion and cataloguing of each method. Discussion about minor adaptation of original or existing methods has been avoided.

2. Basics of solar photovoltaic cell

Fig. 1 represents the simple equivalent circuit of a PV cell with load [10]. The elementary Equation defining the I—V

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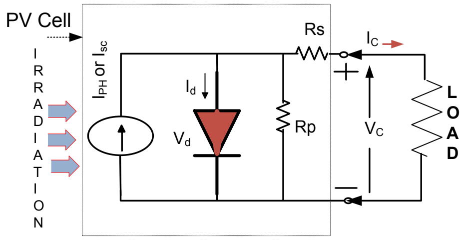

Fig. 1. Simple equivalent circuit of a PV cell.

characteristic of the ideal photovoltaic cell is given by Eq. (1) [8–12].

$$I_C = I_{PH} - I_0 \left[e\left(\frac{qV_d}{kT_C}\right) - 1 \right] \quad (1)$$

$I_{PH} = I_{SC}$ is the short circuit current whose magnitude depends on the area of the cell and is directly proportional to the solar insolation. V_d is the voltage across the diode, k is Boltzmann constant (1.38×10^{-23} J/°K), q is electron charge (1.602×10^{-19} C), I_o is reverse saturation current of diode (0.000025 A) and is calculated using Eq. (2), T_c is reference cell operating temperature (25 °C).

$$I_o = \frac{I_{sc,n} + K_I \Delta T}{\exp\left(\frac{V_{oc,n} + K_V \Delta T}{aVt}\right) - 1} \quad (2)$$

K_I is the current coefficient, K_V is the voltage coefficient, $V_{oc,n}$ is the open circuit voltage at the nominal condition (usually 25 °C and 1000 W/m^2), $\Delta T = T - T_n$ (being T and T_n the actual and nominal temperatures). In a practical PV cell, there is a series of resistance in the current path through the semiconductor material, the metal grid, contacts, and current collecting bus. These resistive losses are lumped together as a series resister (R_s). R_p takes into account the loss associated with a small leakage of current through a resistive path in parallel with the intrinsic device. I–V and P–V characteristic of a PV cell is shown in Fig. 2. The intersection of load line (i.e. I=V/R) and I–V plot of PV cell gives the operating point. R_1 and R_o are different load resistance. R_o corresponds to the load at which MPP coincides with the operating point.

The point at which I_{mp} and V_{mp} meets is the maximum power point [MPP] and this point varies with the change in atmospheric conditions. I_{mp} is the current corresponding to maximum power and V_{mp} is the voltage across cell at maximum power. The open circuit voltage (V_{oc}) decreases

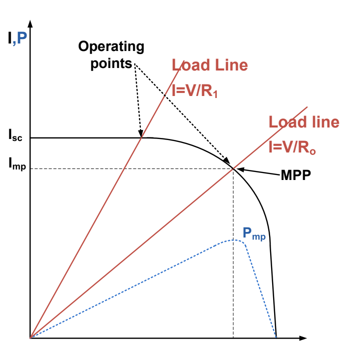

Fig. 2. I–V and P–V characteristics of PV cell.

linearly with the rise in the cell temperature and increases logarithmically with the ambient irradiation, while the short circuit current is a linear function of the ambient irradiation, this is clearly shown in Fig. 3.

To obtain maximum power from the PV array, the operating point should coincide with the MPP at different atmospheric conditions. The process of extracting maximum power from a PV array is done by the maximum power point tracker.

3. MPPT—Requirement

The purpose or role of various algorithms, proposed till date, is to control the duty ratio (D) of the converter used. This is done is such a manner that the actual load line as seen by the PV array coincides with that of a load at which maximum power is extracted from the panel. Four basic types of DC–DC converters are mainly used for this purpose and they are Buck, Boost, Buck-Boost and Cuk converter. For grid connected system or for AC loads generally an inverter is used after DC–DC converter but advancement in research has eliminated one stage by directly converting the panel DC output to AC [6]. Fig. 4 shows the schematic diagram of a PV system with DC–DC converter [2,3,5]. R_{in} is the input resistance of the converter and R_o is the output resistance or load resistance. In Fig. 5 the approximate range of R_{in} for different DC–DC converters have been shown, depending upon the value of R_o, the correct choice of converter can be made [5–7].

4. MPPT classification and details

4.1. Fractional Short Circuit Current method

Numerical methods have shown that there is a linear dependence between I_{mp} and I_{sc} [13]. This gives the Eq. (3) which portrays the main idea of Fractional Short Circuit Current technique for maximum power-point tracking. The MPPT makes the PV array to operate at a fixed percentage of I_{sc} and thus very close to the maximum power point. K_{sc} is a constant of proportionality and is called the "current factor". Its value depends on the type of cell used and is lies between 0.71 and 0.90 [13,14].

$$I_{mp} = K_{sc} I_{sc} \quad (3)$$

The main problem to implement this method is the difficulty of measuring I_{sc} while the PV system is in operation. For

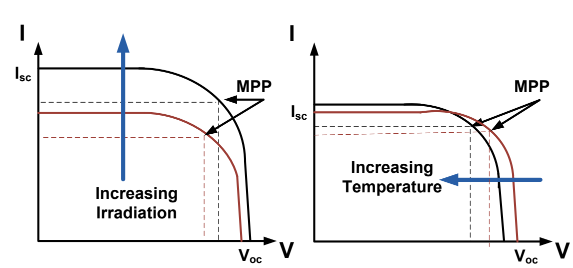

Fig. 3. I–V characteristics of PV cell with change in ambient irradiation & the cell temperature.