Renewable and Sustainable Energy Reviews xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Comparative and comprehensive review of maximum power point tracking methods for PV cells

M.A. Danandeh, S.M. Mousavi G.*

School of Railway Engineering, Iran University of Science and Technology, Tehran, Iran

ARTICLE INFO

Keywords:
Maximum power point tracking
Photovoltaic
PV cell

ABSTRACT

The energy problem is one of the most important and serious problems that humanity is faced with it and this is while the fossil fuels are running out, so finding new sources of energy is one of the challenges of modern man. Solar energy is an available, newable and almost eternal energy which can be converted directly to electrical energy by photovoltaic (PV) cells. Although the use of sunlight costs nothing but PV cells are relatively expensive so it's necessary to extract maximum power from these cells because of economic reasons. To achieve the maximum power point, there are many techniques and also many review papers but just few papers have compared these techniques from economical and technical point of view. This paper presents a review of MPPT techniques using of comprehensive and relatively new classification with emphasizing on comparison of methods.

1. Introduction

The rapid growth of population and industry, technological progress and improvement of life quality have led to an ever-increasing human need for energy so that there is a direct relation between development and consuming of energy. Nowadays the big part of energy comes out by using of fossil fuels but issues like the political and economic crisis, environmental pollution, limitation of fossil resources and etc., have revealed the necessity of finding new sources of energy. Solar energy can be used as one of the required sources for solving these problems. Solar energy is so clean and does not produce any greenhouse gases which means environmental and health costs of generating energy will decrease and also the global warming issue can be controlled so better by using of renewable energy instead of fossil fuels. One of the other benefits of solar energy is that it is worldwide and available such as almost all countries can use it for generating energy without depending to other countries. Being eternal can be assumed as the biggest benefit of solar energy which guarantees the source can be used at least for thousands years so it can be counted as a livelong source.

Additional to the above mentioned, solar energy is free and completely safe with extremely much value of energy. The energy from the sun to the earth's surface is about one thousand times greater than the energy that is released by fossil fuels during a day [1]. The use of PV cells is one of the most common ways to exploit solar energy and directly convert it to electrical energy. PV cells are generally composed of two types of semiconductors which are called as N type and P type. The N-type is located in that part of cell which is in front of sun and the P-type is in the back of cell [2]. Also these cells have non-linear I-V and P-V characteristics which both highly depend to irradiation, ambient temperature [3] and load impedance [4]. Figs. 1 and 2 show the non-linearity of the I-V and P-V characteristics of PV cell and effect of ambient conditions on them. As shown in figures increasement of temperature reduces maximum power of PV cell while increment of irradiance causes increment of it.

Today, the number of installed cells is rapidly increasing and these cells are used in three different types: stand alone, grid connected and hybrid. For example more than 1.5 million photovoltaic systems have been installed in Germany [5] and generated power by them is about 40,093 megawatts (MW) by the end of May 2016 [6]. Of course there are still two important barriers in the path of PV cells, relatively expensive cost and low efficiency. Therefore it is completely necessary to extract maximum power of cells because of economic reasons and growing demand for energy. So many methods have been presented for tracking the maximum power point of PV cells and the most common of them have been reviewed in this paper.

2. Classification of maximum power point tracking(MPPT) methods

There are many ways for classification MPPT methods. Four of the most common ways are listed in next:

* Corresponding author.
E-mail addresses: mohammad.amin.danandeh@gmail.com (M.A. Danandeh), sm_mousavi@iust.ac.ir (S.M. Mousavi G.).

http://dx.doi.org/10.1016/j.rser.2017.10.009
Received 21 November 2016; Received in revised form 24 July 2017; Accepted 3 October 2017

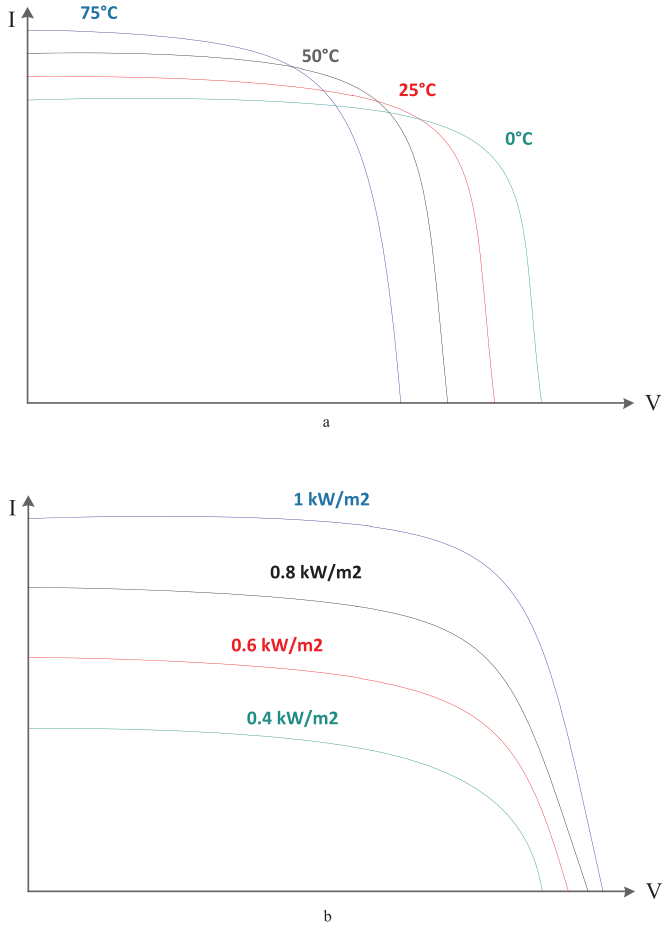

Fig. 1. a : I-V characteristics for 0, 25, 50 and 75 °C. b : I-V characteristics for 0.4, 0.6, 0.8 and 1 kw/m^2.

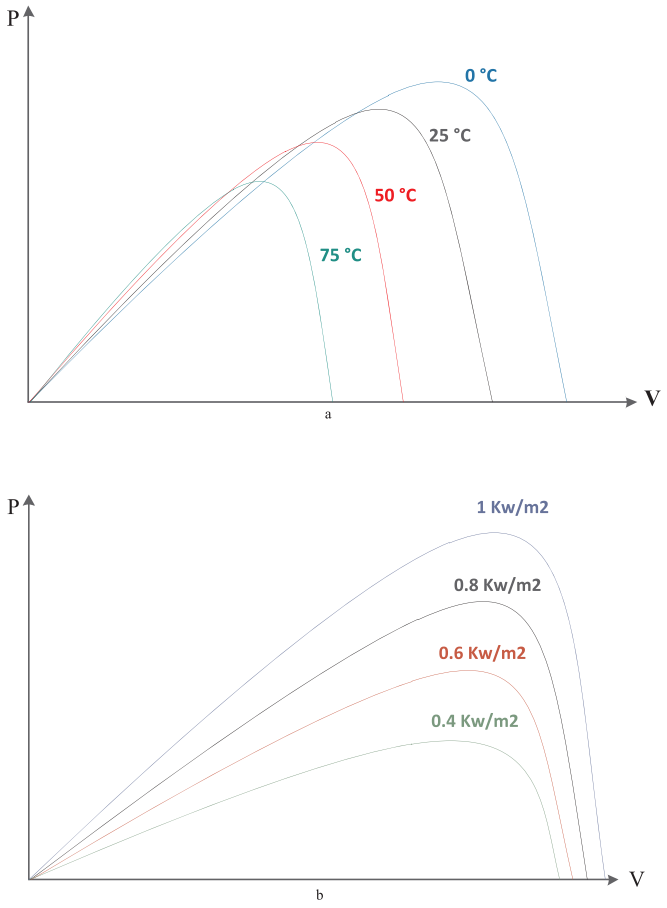

Fig. 2. a : P-V characteristic for 0, 25, 50 and 75 °C. b : P-V characteristic for 0.4, 0.6, 0.8 and 1 kw/m^2.

2.1. Classification according to control mode

In this way, MPPT techniques are divided into two classes, Online (direct) and Offline (indirect). In the online class, tracker does not require to have a priori knowledge about the PV cell while offline methods can not track MPP without it. The main advantage of online methods is being independent of priori knowledge which means online methods can work in different conditions.

2.2. Classification according to number of variables

MPPT methods can belong to one of one-variable or two-variable groups. One-variable group consists of methods that need to measure just one parameter like current, voltage or temperature but two-variable group includes of methods which need to measure two parameters like current and voltage. It is clear that few numbers of variables means few numbers of sensors.

2.3. Classification according to result of tracking

In this way, there are two groups of methods, true MPPT methods and not true. "True" group includes of methods which tracks maximum power point exactly while "not true" methods use approximation for tracking MPP which causes good speed for these methods but the result of them is some point with high power and close to MPP but it is not exactly maximum power point.

2.4. Classification according to tracking style

It can be a good way for classification MPPT methods. According to this way, methods that have same idea for tracking MPP go to the same class. The main advantage of this way is that methods which are in same group have some same advantages, drawbacks and working style. This way has been utilized for classification of methods in this paper which is shown in Fig. 3.

3. MPPT methods review

3.1. Curve fitting

The main idea of this method is providing a polynomial which can approximate the P-V characteristic of PV cell. This purpose can be achieved by testing cell under different conditions, collecting experimental data (P,V and etc.) and using curve fitting techniques. The most common approximation for P-V characteristic of cell is cubic order polynomial as (1) [7].

$$P = a*V^3+b*V^2 + c*V + d \quad (1)$$

The coefficients of this relation are strongly dependent on temperature of cell so (1) can be rewritten as (2).

$$P(V,T_{cell}) = a(T_{cell})*V^3+b(T_{cell}) *V^2+c(T_{cell})*V + d(T_{cell}) \quad (2)$$

According to Fig. 4 at the MPP, power variation with voltage is zero, so it is possible to calculate voltage of MPP by (3)–(5).