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A novel linear tangents based P & O scheme for MPPT of a PV system

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ABSTRACT

This paper first presents an overview on traditional Maximum Power Point Tracking (MPPT) algorithms. Traditional algorithm can be easily implemented using analog or digital devices. As traditional algorithms suffer from low efficiency, oscillations in steady state power and poor dynamic performance, a novel MPPT scheme using Linear Tangents based Perturb & Observe (LTP & O) is proposed in this paper. In order to validate their performance, proposed scheme and other traditional algorithms are simulated using Matlab/Simulink. Simulated results provide evidence that the proposed method has better accuracy, increased efficiency, low oscillation, improved steady state and dynamic performance compared to traditional methods.

1. Introduction

Around the globe, significance and usage of solar energy is seeking priority among alternate energy resources due to its eco-friendly nature and salient features [1]. Depleting traditional resources, environmental conditions, improved semiconductor material, and long term profits are some of the reasons tending the usage of inexhaustible solar energy, electrical energy obtained is free from pollution as the system doesn't involve any machine [2]. In general, solar energy is preferred for water pumping, street lighting, cooking, electric vehicles and space stations [3]. It is advisable to supply electric power generated from solar energy to remote areas in absences of power grid.

Solar power generating system can be operated in hybrid combination along with other renewable energy resources such as wind or tidal reliable [4]. A Photovoltaic (PV) panel directly converts solar energy to useful electrical energy [5]. The operating characteristics of a PV panel are influenced by irradiance and temperature on the panel surface.

However, the drawback of PV system is conversion efficiency of commercial PV panel which lies between 7 and 19% [6]. In order to improve the conversion efficiency, structure of PV cell has to be customized which is not economical. Alternate lies in optimizing PV power through MPPT algorithm. When PV system is operated at Maximum Power Point (MPP) maximum efficiency is expected from the system [7]. In order to operate PV system at MPP several methods have been proposed in the literature, such as Perturb & Observe (P & O) method [8], Incremental Conductance (INC) method [9], Hill Climbing method [10], Fractional Open Circuit Voltage (FOCV) method [11], Fractional Short Circuit Current (FSCC) method [12], Artificial Intelligence based on Fuzzy logic controller [13], Neural Network [14,40] and Genetic Algorithm [15] and also different combinational techniques to increase the tracking speed and to reduce the oscillations in the P & O method [16].

Fangrui et al. [17] presented intelligent variable step size INC method experimentally in order to improve MPPT speed and accuracy. Ahmad et al. [18] presented fuzzy logic controller based MPPT which has better performance compared to PI controller. Kheldoun et al. [19] presented golden section method for standalone PV system. This method is valid for fast changing weather conditions. Dounis et al. [20] presented a digital implementation of novel adaptive neural control MPPT to improve limitations associated with traditional methods. Stefan et al. [21] presented a Global MPPT based on genetic algorithm which reduces simulation time. Killi et al. [22] presented a modified P & O method to control drift in power. Yali et al. [23] presented a hybrid MPPT based on Constant Voltage and Atken interpolation technique with better steady state and dynamic performance [24].

Performance of any MPPT can be evaluated based on tracking speed, accuracy and stability. In this paper, PV system is simulated using different MPPT control algorithms at same operating conditions in Matlab/Simulink environment. Apart from this, a novel MPPT scheme is presented using Linear Tangent based Perturb & Observe (LTP & O) which has better accuracy, efficiency, steady state and dynamic performance compared to traditional methods. This paper is organized as follows: after introduction a detailed mathematical modeling of PV system is presented in Section 2, MPPT algorithms in Section 3, simulation results and discussion in Section 4 and conclusions are given in Section 5.

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2. Mathematical modeling of PV system

A PV system is a combination of PV panel, dc-dc converter, MPPT controller and load as shown in Fig. 1. The MPPT controller takes PV panel voltage and current values as input, performs necessary computations and generates required gate pulse for the switching element in the converter, such that the impedance mismatch between source and load can be minimized [25].

2.1. PV panel

A group of PV cells connected together forms a PV panel. In order to get high output voltage, PV cells are connected in series and parallel connected PV cells yields high output current [26]. In this paper, highly efficient multi crystal Kyocera KY200GT solar panel is used because its solar cell conversion efficiency is over 16% [27]. Equivalent circuit of a single diode PV panel is depicted in Fig. 2. Irradiance and temperature are responsible for the I-V characteristic equation expressed as [28]

$$I = I_{SC}\left\{1 - K_1\left(e^{\left(\frac{V}{K_2 V_{OC}}\right)}\right) - 1\right\} \tag{1}$$

where I_{SC} is the light generated current (A), V is the PV panel output voltage (V), V_{oc} is the open circuit voltage (V), I is the PV panel output current (A), K_1 and K_2 are the coefficients expressed as

$$K_1 = \left(1 - \frac{I_M}{I_{SC}}\right)e^{\left(\frac{-V_M}{K_2 V_{OC}}\right)} \tag{2}$$

$$K_2 = \frac{\left(\frac{V_M}{V_{OC}} - 1\right)}{\ln\left(1 - \frac{I_M}{I_{SC}}\right)} \tag{3}$$

where I_M is the current at MPP and V_M is the voltage at MPP. Fig. 3(a) and (b) shows P-V and I-V characteristics of the PV panel at 25 °C temperature and at different irradiance Fig. 3(c) and (d) depicts P-V and I-V characteristics at constant irradiance of 1000 W/m^2 and different temperatures. PV panel specifications are given in Appendix. Output power of the PV panel is given as

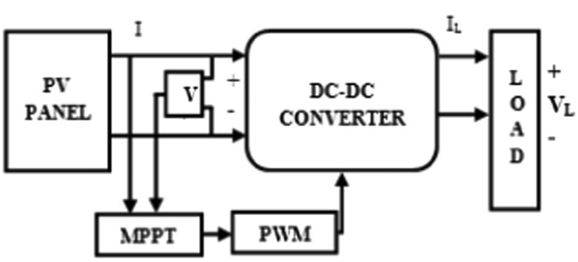

Fig. 1. Block diagram of PV system.

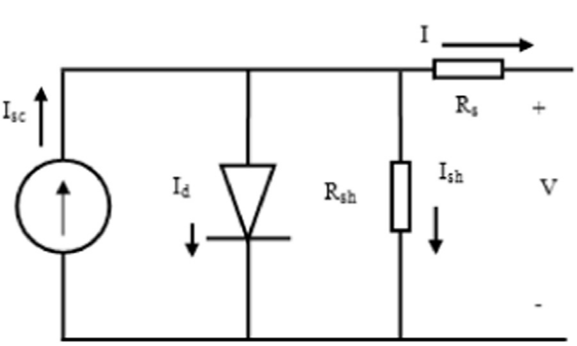

Fig. 2. Equivalent circuit of a PV panel.

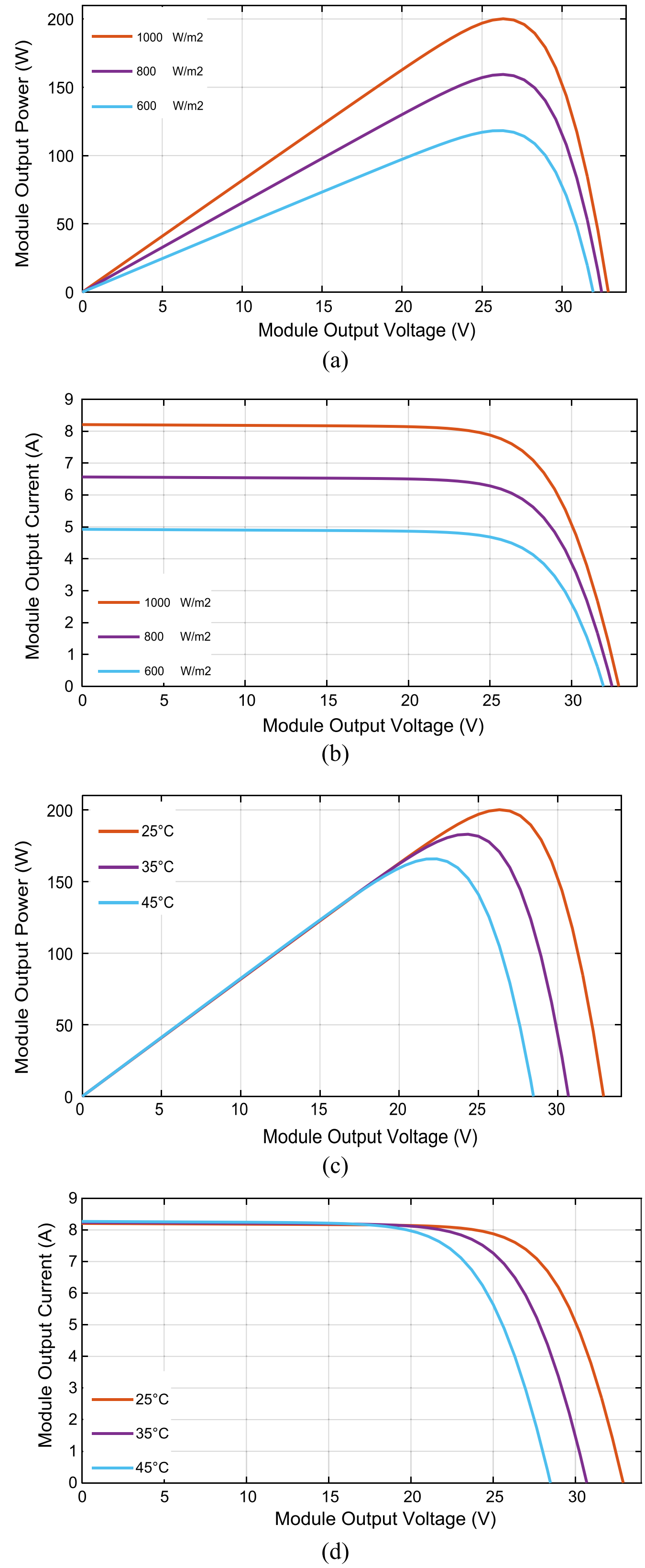

Fig. 3. P-V and I-V characteristics of PV system.

$$P = V{*}I_{SC}\left\{1 - K_1\left(e^{\left(\frac{V}{K_2 V_{OC}}\right)} - 1\right)\right\} \tag{4}$$