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Maximum Power Point Tracking Algorithm for Photovoltaic Systems under Partial Shaded Conditions

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Abstract: The P-V characteristic of photovoltaic (PV) module under standard conditions (temperature and irradiation) presents one unique maximum, which can easily be tracked using conventional Maximum Power Point Tracking (MPPT) techniques. But under partial shading conditions, photovoltaic array exhibits several local maximum power points, only one of them is the global maximum. Therefore, the above techniques may fail to track the global maximum, reducing the extracted power as a result. The present paper deals with the problem of tracking the global maximum under different conditions. A new Perturb and Observe (P&O) modified algorithm is then presented. The algorithm monitors the maximum power point voltage and triggers a current-voltage sweep only when a partial shadow is detected, minimizing then the power loss due to repeated current-voltage sweeps.

Keywords: Photovoltaic Energy, Partial shading, MPPT algorithms.

1. INTRODUCTION

Solar energy is a vast and inexhaustible resource. Once a system is in place to convert it into useful energy, the fuel is free and will never be subject to the ups and downs of energy markets. Furthermore, it represents a clean alternative to the fossil fuels that currently pollute air and water, threaten our public health, and contribute to global warming. Given the abundance and the appeal of solar energy, this resource is poised to play a prominent role in our energy future. Photovoltaic cells or panels are one of different ways of generating electricity from solar energy. Due to the low efficiency of solar panels, PV system needs to maximize the energy generated. Every variation of temperature or solar irradiation causes changes in the PV current and power which needs to define a new point of operation. Therefore, a Maximum Power Point Tracking (MPPT) is generally invoked in PV systems.

The use of MPPT algorithm allows extracting the maximum power of a photovoltaic (PV) system under standard conditions; this maximum depends on temperature, irradiation, or nonlinearity of a PV. In case of Partial shaded conditions, several MPPs occur on the P-V curve, (Diaz-Dorado *et al*. 2010); therefore, a Global MPPT algorithm is required. Many techniques have been proposed; Perturb and Observe (P&O) [Ahmed M. Atallah, Almoataz Y. Abdelaziz, and Raihan S. Jumaah, (2014)]. Incremental Conductance and short circuit method (Kumar *et al*., 2014) are some popular approaches which are sample to be implemented and work satisfactorily in normal conditions, but could fail to track global MPP when the irradiance is not uniform. Other proposed methods allow solving the problem of partial shadow. Except periodic scan algorithms (in which an important quantity of energy is lost due to repeated scan) , these methods are in general not easy to implement, for example Differential Evolution (Taheri *et al.,* 2010), or very costly because of the need to use climatic sensors (Donny *et al*., 2012), or solution that requires database (Spataru *et al*., 2013).

This paper proposes an algorithm which allows tracking the global maximum power whatever are the conditions of radiation. The effectiveness of the proposed algorithm is checked by several simulation scenarios.

The paper is organized as follows: in Section 2, the PV system under study is described and the objective is clearly presented. Section 3 is devoted to controller design and analysis. The controller tracking performances are illustrated by numerical simulation in Section 4.

2. PRESENTATION OF PV SYSTEM AND OBJECTIVES

A typical configuration of grid connected photovoltaic system is shown in Fig.1.

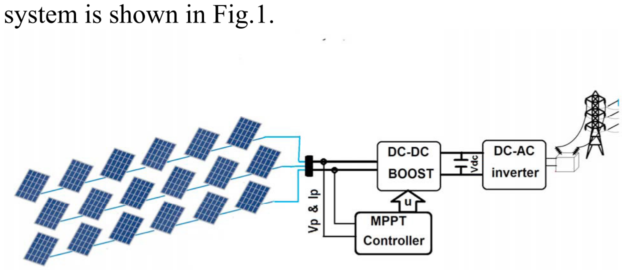

Fig. 1: typical configuration of grid connected photovoltaic system.

It consists of the following components:

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- A photovoltaic array which consists of an arrangement of N_{sp}-series and N_{pp}-parallel panels
- A boost dc-dc converter (used for boosting the array voltage and achieving MPPT for PV array),
- An inverter resorted to ensure DC-AC power conversion,
- An output filter and an isolation transformer connected to the grid.

2.1 PV Array Model

The equivalent circuit of PV cell (Bonkoungou *et al*., 2013) is shown in Fig.2

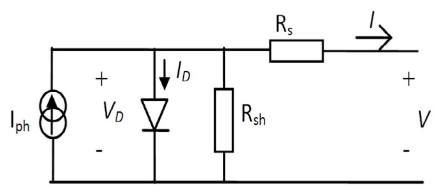

Fig.2: PV module equivalent circuit.

The corresponding (I-V) characteristics are given by the following equation (Nagayoshi and Atesh, 2005, Woyte and Belmansa, 2003):

$$I = I_{ph} - I_o\{\exp(AV_d) - 1\} - \frac{V_d}{R_p} \tag{1a}$$

Where

$$A = \frac{q}{N\gamma KT} \tag{1b}$$

$$V_d = V + R_s I \tag{1c}$$

$$I_o = I_{or}\left[\frac{T}{T_r}\right]^3 \exp\left[\frac{qE_{GO}}{\gamma K}\left(\frac{1}{T_r} - \frac{1}{T}\right)\right] \tag{1d}$$

$$I_{ph} = \left[I_{scr} + K_I(T - T_r)\right]\frac{\lambda}{1000} \tag{1e}$$

Where I_{ph} is the photocurrent (generated current under a given radiation); I_o is the cell reverse saturation current; I_{or} is the cell saturation current at T_r; I_{scr} is the short circuit current at 298.15K and 1kW/m2; K_I is the short circuit current temperature coefficient at I_{scr}; λ is the solar radiation; E_{GO} is the band gap for silicon; γ is the ideality factor; T_r is the reference temperature; T is the cell temperature; K is the Boltzman's constant and q is the electron charge; R_s is the series resistance and R_p is the shunt resistance.

A PV panel consists of N_{sc} cells in series. The output voltage of one panel is given by the following equation:

$$V_p = N_{sc}(V_d - R_s I) \tag{2}$$

The photovoltaic generator (PVG) (also called PV array) is composed of many PV panels connected in N_{sp}-series and N_{pp}-parallel panels in order to provide the desired values of output voltage and current. The output voltage and current of a PVG can be given by the following equations:

$$V_g = N_{sp} V_p \tag{3a}$$

$$I_g = N_{pp} I \tag{3b}$$

In this paper, the PV array considered is arranged in three strings ($N_{pp} = 3$), each string consists of six panels ($N_{sp} = 6$). The PV panels are of the type NU-183E1. The corresponding electrical characteristics are listed in Table 1.

Table 1: Electrical specifications for the solar module NU-183E1

Parameter	Symbol	Value
Maximum Power	P_m	183.1W
Short circuit current	I_{scr}	8.48 A
Open circuit voltage	V_{oc}	30.1V
Maximum power voltage	V_m	23.9 V
Maximum power current	I_m	7.66A
Number of series cells	N_{sc}	48

2.2 Boost dc-dc converter model.

Fig. 3 shows the circuit of boost dc-dc converter used to boost the array voltage and achieving MPPT for PV arrays. The converter operating mode is the so-called Pulse Width Modulation (PWM).

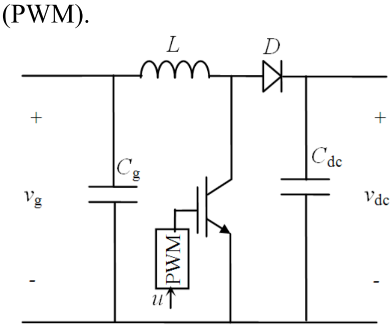

Fig.3: Boost dc-dc converter circuit

In this paper, the focus is made on the MPPT control part, therefore the following static characteristic of dc-dc power converter is considered:

$$v_g = (1-u)v_{dc} \tag{4}$$

Where: