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A simscape based design of a global maximum power point tracker under partial shading condition

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Abstract

This manuscript presents the simulation of a global maximum power point tracker (GMPPT) under partial shading effect for a solar photovoltaic module using MATLAB/SIMSCAPE. Conventional maximum power point tracking techniques such as fuzzy logic and "perturb and observe" do not guarantee the operation of the system on its maximum power point (MPP) and might result in a local power point under partial shading conditions. Photovoltaic characteristics, I-V and P-V curves, under partial shading conditions become more complex and generally result in more than one power peak. However, only the highest peak is considered as the global maximum power point (GMPP) while all others are considered local maxima's and hence, are (LMPP) This manuscript will focus on forcing the photovoltaic system to operate on its global maximum power point and hence, result in the maximum extracted power under shading and different environmental conditions.

Keywords: Solar Cells, Photovoltaic, PV Module, MATLAB/Simulink/Simscape, GMPPT, LMPPT.

1. Introduction

Photovoltaic technology is considered very promising and recently witnesses very rapid development. In a photovoltaic system, the most important element is the photovoltaic cell and is still being developed to extract more energy and results are extremely encouraging.

Among the major challenges of a PV system are their low efficiency and high initial cost per unit output power. Photovoltaic system efficiency can be viewed as the ability of photovoltaic panels to convert sunlight into human usable energy [1, 2]. Maximum power point tracking (MPPT) technique is used to track the maximum power and to force the photovoltaic systems to operate on its maximum extracted power or at its highest possible efficiency. The PV system has a unique maximum power point on the non-linear P-V curve depending on irradiance and temperature.

2. Shadow Effects

The partial shading of PV panels result usually in very challenging problems namely "hot spots" and multiple power peaks. Areas of high temperature known as "hot spots" can severely damage the associated cells and the multiple power peaks usually lead to a further decrease in the system efficiency. In modern PV modules, small electronic components are used as a part of the system known as "bypass diodes". These diodes allow the current of the un-shaded cells to be bypassed by that of the shaded ones in order to avoid hot spots.

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3. Maximum Power Point Tracking (MPPT)

The main objective in employing MPPT is to obtain the maximum power from PV panels under various environmental conditions [3]. MPPT techniques differ in number of sensors, cost, complexity, effectiveness and correct tracking for different irradiations and temperatures. When environmental conditions such as temperature and irradiation change, the MPPT makes sure the PV system operates as close as possible to its maximum power operating point. It is then desired to design a controller that forces the PV system to operate at its maximum extracted power [4]. Conventional Maximum Power Point Tracking (MPPT) techniques are working efficiently in normal conditions but the tracking of the MPP gets more complex when the panel is subject to shading. Under partial shading conditions, the non uniform irradiation throughout the PV panels results on hot spots and multiple power peaks [5-9]. In the case of partial shading, multiple maxima points will appear on the P-V curve. The tracking of the global maximum power point become difficult and usually is not guaranteed by conventional MPPT controlling techniques.

4. Modeling

The basic element of a PV module is the PV cell. In Simscape workspace, a PV cell block can be used to exactly simulate the behaviour of a real PV cell. More than one PV cell block can be combined, to make a PV module, in a series or parallel fashion. Figure1 illustrates the Simscape block diagram of the PV system under partial shading conditions.

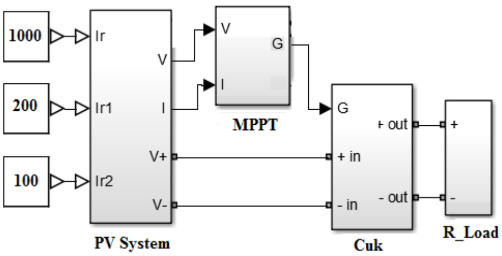


Fig. 1. Matlab /Simscape Model of PV system under partial shading condition.

The adopted PV Cell specifications are as shown in Table1 below:

Table1. The PV Cell Specifications:

Number of cells in series	108
Open circuit voltage	30V
Short circuit current	5.5A
Voltage at MPP	20.4V
Current at MPP	4.4A
Maximum power	90W

The P-V characteristics of the partially shaded module is illustrated in Figure2

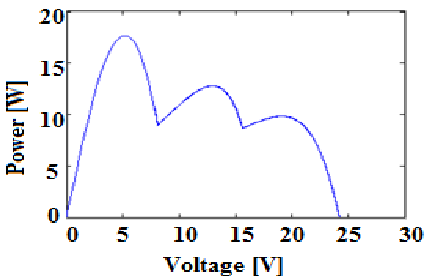


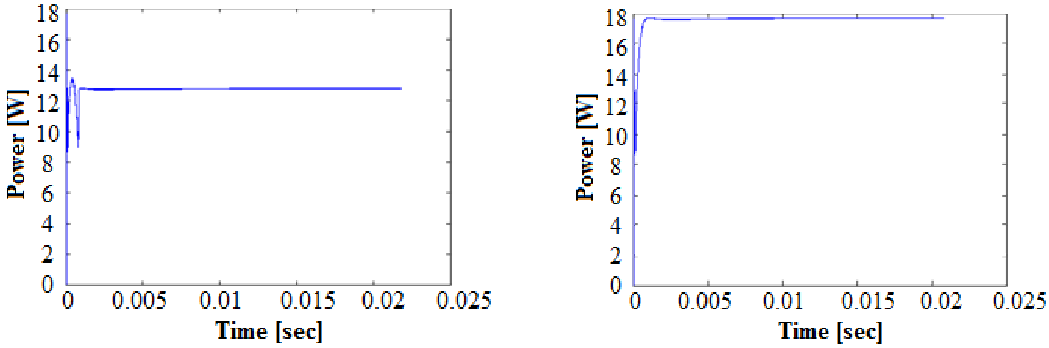
Fig. 2. P-V Characteristics under shading effect.

The P-V curve shows three maximum power peaks and obviously, the one with highest only one of them is considered as the global maximum power point. In this illustration, the value of the global maximum power point is 18W.

5. Perturb and Observe

The Perturb & Observe technique is the most widely used algorithm in stand-alone PV systems. The technique consists of measuring the current and voltage and consequently, the associated power p_1 is computed. This is then followed by a small perturbation of the voltage Δv, and hence, the duty cycle ΔD of the DC-DC convertor is computed and the corresponding power p_2 is then calculated. The power p_2 is compared to p_1 and if $\Delta p = p_2 - p_1$ is positive then the perturbation is in the right direction. If not, then the perturbation is reversed.

Figure3 shows that when the initial duty cycle is equal to 0.47, the system tends to operate on one of its local peaks (LMPP). However, when the initial duty cycle is equal to 0.75, the system tends to stay on its global peak (GMPP).



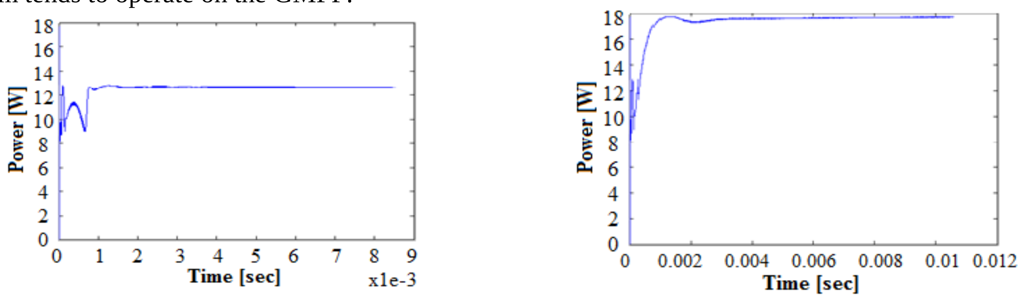
(a) (b)

Fig. 3. Power versus time curve (a) when initial duty cycle D=0.47, (b) when initial duty cycle D=0.75

6. Fuzzy Logic Control

Among the reasons motivating the use of fuzzy logic control (FLC) in industrial process are its ease of use, its no need of an accurate mathematical model and the possibility of using it in linear and nonlinear process. Fuzzy logic technique is similar to the P&O method in the sense that both methods do not guarantee the system to operate on its GMPP and usually tend to stay on a local maximum power point. Moreover, the reachability of the GMPP usually depends on the initial duty cycle of DC-DC converter.

Changes in voltage and power are the inputs variables into the fuzzy controller. The output from the fuzzy logic controller is in general, the change of the duty cycle. Figure 4 shows that when the initial duty cycle is equal to 0.47, the system tends to stay on LMPP, but when the initial duty cycle is set equal to 0.75, the system tends to operate on the GMPP.



(a) (b)

Fig. 4. Power versus Time curve (a) when initial duty cycle D=0.47, (b) when initial duty cycle D=0.75

7. Improved P&O Technique

The previous simulations illustrates that both the P&O and the fuzzy logic controller are working very well under normal conditions but they usually do not guarantee the PV system to converge to its GMPP. The simulation illustrates that the system converges to a local power peak which consequently, reduces the efficiency of the PV system. The improved modified P&O technique is an evolution of the conventional one and, in general, consists of splitting the P-V curve into several parts. Once segmented, the controller starts a preliminary scanning and continuously store the highest value of the power of the segmented part and also the value of the corresponding duty cycle. Once the scanning process is completed and the maximum values of power and duty cycle are recorded for each section, the technique then works as the conventional P&O and converges to the highest power point.
The improved P&O technique flow chart is illustrated in Figure5.

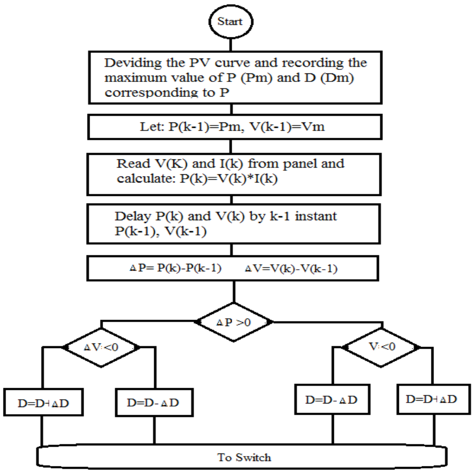


Fig. 5. Improved P & O Algorithm flow chart

The proposed system is tested under three radiation levels, 100, 200 and 1000W/m^2. As shown in Figure 6, the system successfully reaches its GMPP under the three radiation levels in less than 0.025 second and without taking into account the value of initial duty cycle as expected.

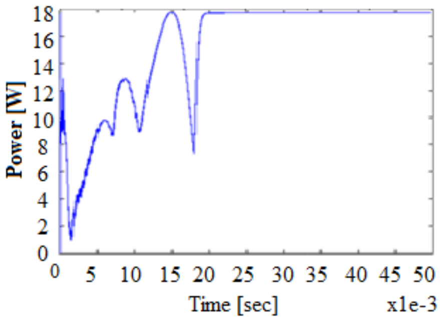


Fig. 6. Power versus Time when using improved P&O technique

8. Conclusions

MATLAB/SIMSCAPE software has been developed for the design and simulation of a MPPT controller of a photovoltaic system. Simulation of PV characteristics and its performance are accomplished for different irradiations and weather conditions. Different control techniques are assumed and their accuracy and convergence are compared in the MATLAB/SIMSCAPE environment. Partially shaded PV panels performance with MPPT controllers are simulated and the power multiple peaks problem is addressed. Conventional MPPT techniques do, in general, not converge towered the highest power point and consequently, result in lower extracted power and hence, efficiency. However, a modified Perturb and observe technique is proposed instead and simulations demonstrate accurate tracking and fast convergence for all considered initial duty cycles.

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