

Maximum Power Point Tracking Algorithm for PV Systems using Partially Shaded Conditions

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ABSTRACT: The performance of a photovoltaic (PV) array is affected by temperature, solar insulation, shading, and array configuration. Often, the PV arrays get shadowed, completely or partially, by the passing clouds, neighboring buildings and towers, trees, and utility and telephone poles. Under partially shaded conditions, the PV characteristics get more complex with multiple peaks. This makes the tracking of the actual maximum power point (MPP) a difficult task. In this paper, a simple technique of MPPT is presented for photovoltaic power generation system to solve the aforementioned problems. It realizes simple control system to track the real maximum power point even under non-uniform or for rapidly changing insulation conditions. The proposed technique in the first stage searches the I-V characteristic of the PV arrays by scanning the whole range. Simulation and some selected experimental results are presented to prove the feasibility of the proposed technique.

KEYWORDS: Photovoltaic (PV) array, MATLAB Simulink, Maximum Power Point Tracking (MPPT)

I. INTRODUCTION

Renewable energy sources such as solar energy are acquiring more significance, due to shortage and environmental impacts of conventional fuels. The photovoltaic (PV) system for converting solar energy into electricity is in general costly and is a vital way of electricity generation only if it can produce the maximum possible output for all weather conditions. In general, a PV source is operated in conjunction with a dc–dc power converter, whose duty cycle is modulated in order to track the instantaneous MPP of the PV source. The output of the PV depends highly on an insulation condition and a surface temperature of the PV array. Moreover, there are several local maximum power points in the P-V curve under non-uniform insulation, whereas only one MPPT point is exist under uniform insulation for a given temperature and insulation. Several tracking schemes under uniform solar insulation have been proposed [1]–[2]. Among the popular tracking schemes are the perturb and observe (P&O) or hill climbing [3]–[4], incremental conductance [7], short circuit current [1], open-circuit voltage [6], and ripple correlation approaches [5]. Some modified techniques have also been proposed, with the objective of minimizing the hardware or improving the performance [6], [8]–[9]. However, these methods cannot readily track immediate and rapid changes in environmental conditions or non-uniform insulation of the PV modules. The non-uniform insulation of the PV modules which are connected both in series and in parallel depends on several factors such as the incidence angle of solar ray to the module, shadows full-or-partial, and so forth. Under partially shaded conditions, (e.g., due to clouds, trees, etc.), the P–V characteristics get more complex, displaying multiple peaks. There is a need to develop special MPPT schemes that can track the true MPP under these conditions. In order to solve this problem, several methods have been proposed. Some Literatures are based on Fuzzy theory [1], and some others use complicated techniques [3],[4]. Another Literature [7] has proposed a two-stage method to track the MPP. In the first stage, the operating point moves into the vicinity of the MPP on the load line $R_{pm} = V_{pm}/I_{pm}$, and in the second stage, it converges to the actual MPP. V_{pm} and I_{pm} are approximately equal to 80% and 90% of the open-circuit voltage VOC and short-circuit current ISC of the PV array, respectively. However, in this method, if the actual MPP lies on the left side of the load line (R_{pm}), i.e., $R_{pm} > R_{actual}$ (where $R_{actual} = V_{actual}/I_{actual}$), the operating point is temporarily shifted to 90% of VOC, thereby missing the actual MPP. In this

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Vol. 5, Issue 12, December 2016

paper, we propose a simple and practical approach for commercial base use. This method is based on two stages; in the first stage the controller searches the I-V characteristic of the PV regularly at certain specified time using large value of step of the P&O method with storing the actual maximum power point and its corresponding duty cycle. As this obtained MPPT point is not the exact one due to the used large step, a second stage of the controller is designed to oscillate around the obtained MPP point by using the conventional P&O algorithm with a small step. In another word, the algorithm during the first stage operates with large step to reduce the scanning time of the I-V characteristic curve, then after obtaining the approximated MPP, the algorithm oscillates around this MPP with a small step (delta) to provide the exact point with a small oscillation.

As mentioned above, electrical characteristics of PV module are affected by environmental conditions such as temperature, solar irradiation dusts accumulation and shadow caused by bird's clouds and so on. To study the effects of the previous environmental factors a MATLAB model was proposed the model takes into accounts most of the environmental conditions that affect the electrical characteristics of the PV.

The paper continues as follows: Section II discuss the mathematical model of PV. In Section III, the proposed MPPT algorithm is described. In section IV, the implementation and the experimental results are described. Finally, conclusions are presented in section V.

II. CHARACTERISTICS OF PV SYSTEM

The photovoltaic cell converts the light energy into electrical energy depending on the irradiation of the sun and temperature in the atmosphere. Basically PVC is a PN junction diode [3] [4]. But in PN junction diode DCI AC source is needed to work, but here light energy is used as a source to produce DC output. PVC is a current control source not a voltage control source. The equivalent electrical circuit diagram of PVC is shown in the Figure 2.

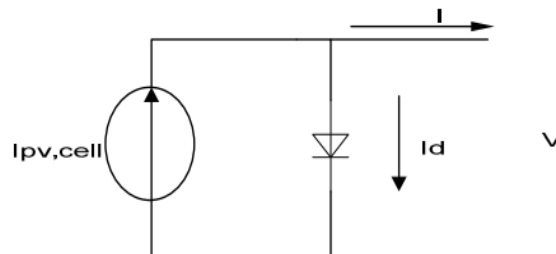


Figure 1: Show ideal photovoltaic cell equivalent circuit

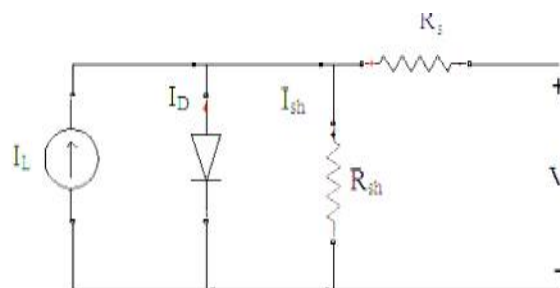


Figure 2: Equivalent Electrical Circuit of PVC

$$I_D = I_0 [\exp(V + IR_s) / KT - 1] \quad (1)$$

Therefore PVC output current is given in equation 2.

$$I = I_L - I_D - I_{sh} \quad (2)$$

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 12, December 2016

$$I = I_L - I_0 [\exp(q(V + IR_s) / KT - 1) - (V + IR_s) / R_{sh}] \quad (3)$$

Where I_D the diode is current, R_{sh} is the shunt resistance, I_L is the light generated current of solar array. Solar cell is basically a p-n junction fabricated in a thin wafer or layer of semiconductor. The electromagnetic radiation of solar energy can be directly converted electricity through photovoltaic effect. Being exposed to the sunlight, photons with energy greater than the band-gap energy of the semiconductor are absorbed and create some electron-hole pairs proportional to the incident irradiation. Under the influence of the internal electric fields of the p-n junction, these carriers are swept apart and create a photocurrent which is directly proportional to solar insolation. PV system naturally exhibits a nonlinear I-V and P-V characteristics which vary with the radiant intensity and cell temperature.

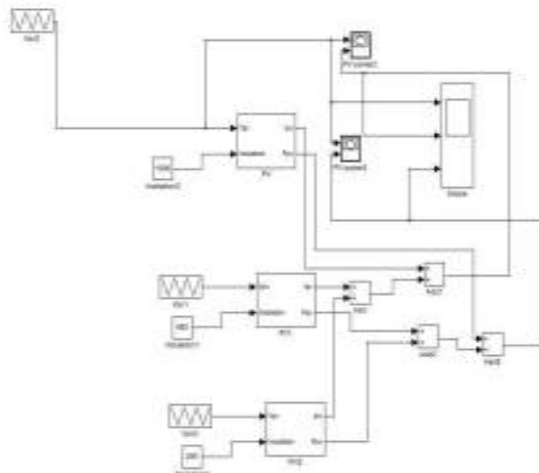


Figure 3: PV array with partial Shading

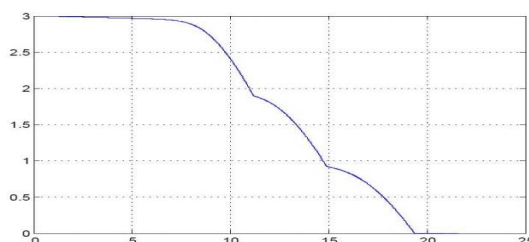


Figure 4: I-V characteristic of PV array under partial shading condition

III. MPPT ALGORITHM USING PARTIALLY SHADED CONDITION

Figure 5 indicates the characteristic output power curve for the solar cell from simulation under a given temperature and irradiance. MPPT control has been proposed and implemented for extracting the maximum power from the PV cell. PV array voltage (i.e. incrementing or decreasing) and comparing the PV output power with that of the previous perturbation cycle. If the perturbation leads to an increase/decrease in array power, the subsequent perturbation is made in the same/opposite direction. In this manner, the peak power is tracked continuously. But this algorithm has two weaknesses.

- When shading occurs, the reversal of the voltage can be observed in that specific section and now the bypass diode in parallel will conduct the current. The results are:

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 12, December 2016

- The current of the un-shaded section flows through the bypass diode and the power/voltage characteristic shows a second local maximum
- The shaded cell is only loaded with that fraction of power produced by the remaining unshaded cells of that section
- When the number of cells which are bridged by the by-pass diode is not too high, the level of the breakthrough voltage will not be reached.

But there are also some draw backs resulting from the by-pass diodes: Higher cost for the module production and assembly problems of the by-pass diodes. Losses in the by-pass diode in the case of shading.

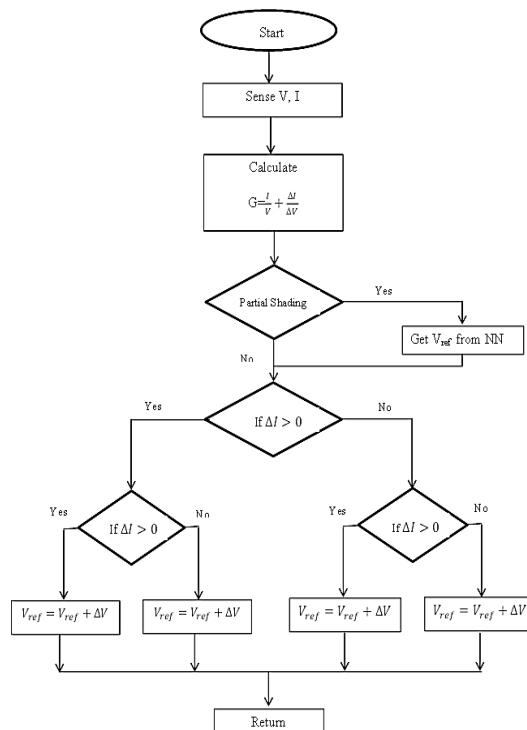


Figure 5: Flowchart of the proposed MPPT algorithm

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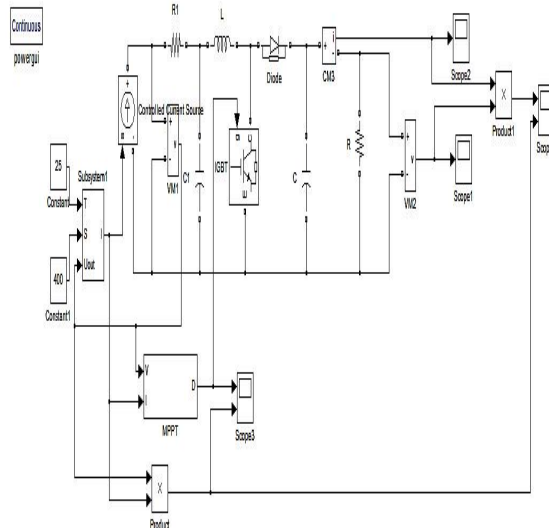


Figure 6: Simulink model for partial shading of MPPT algorithm

The PV module is connected to a variable DC voltage source for measuring its I-V and P-V characteristics. It is modeled as three strings of 20 series-connected cells in parallel with bypass diodes that allow current flow when cells are shaded or damaged. Standard irradiance of 1000 W/m² is applied on the first string of 20 cells while partial shading is applied on strings 2 (cells 21-40) and string 3 (cells 41-60), resulting in respective irradiances of 300 W/m² and 600 W/m². Simulate the model. The global I-V and P-V characteristics are plotted at the end of simulation.

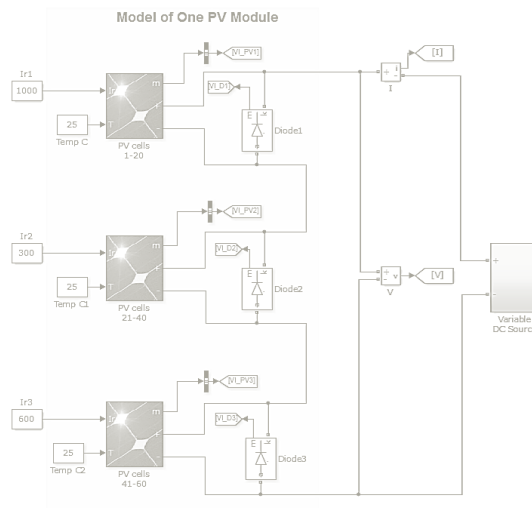


Figure 7: Simulink model for partial shading with bypass diode of MPPT algorithm

Note that the P-V curve exhibits three maxima. When this PV module is connected to a voltage-sourced converter, this may be challenging for the Maximum Power Point Tracking (MPPT) algorithm to converge on the highest peak. The Global Maximum Power Point (GMPP) ($P_m = 104 \text{ W}$) indicated by a red circle on the figure is 34% lower than the expected maximum power ($250/3 * (1 + 0.3 + 0.6) = 158 \text{ W}$).

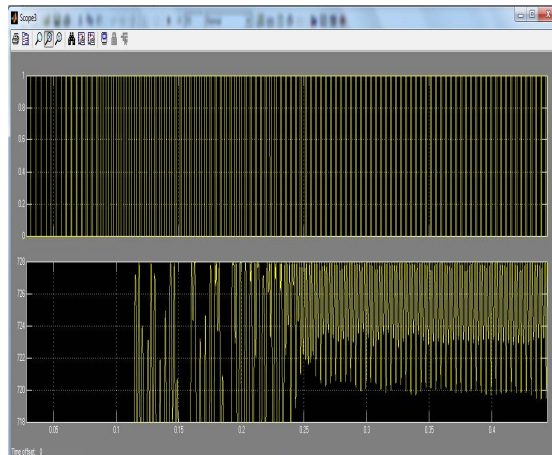


Figure 8: Response of the switching frequency of the PV array

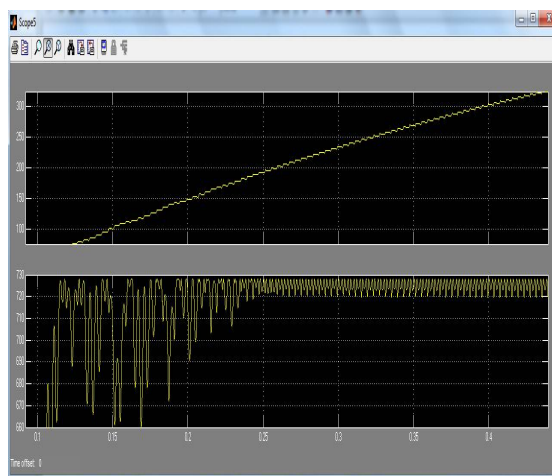


Figure 9: Response of the inverter current P&O and the proposed MPPT algorithm

IV. CONCLUSION

In this paper, a simple technique of maximum power generation systems based on partial to realize a simple control system to track the real maximum power point even under non-uniform or for rapidly changing insulation conditions. The proposed technique in the first stage implements a survey for the I-V characteristic of the PV arrays to detect an approximated MPP.

A MATLAB-Simulink based PV module model is presented in this paper, which includes a controlled current source. Various PV array simulation schematic could be created by the proposed model, and parameters of irradiance and temperature of each PV module model can be set independently. The PV array simulation model allows us to investigate the characteristics of a PV array under various conditions of different irradiance and temperature, especially under condition of partially shading.

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Vol. 5, Issue 12, December 2016

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