Maximum Power Point Tracking under Partial Shading condition

Muhammad Fayyaz Kashif, Yongsoon Park, Seung-Ki Sul

Seoul National Univ., 301 dong, Rm 618

Daehak-dong, Gawanak-gu Seoul 151-744, KOREA

Abstract- Partial shading on a Photo Voltaic panel can generate the local maximum power points on the power-voltage curve of the panel. Presence of the local peaks can disturb the efficient operation of maximum power point tracking (MPPT).In this study, the MPPT under partial shading condition is investigated. To circumvent the trappings into the local peaks, the results of the study are enumerated and discussed.

1. Introduction

Photovoltaic (PV) systems are gaining importance with increasing electric energy demand. However, electrical power from a PV system is varying depending on the local weather conditions, i.e., irradiation and temperature. Therefore, a maximum power point tracking (MPPT) method is needed to consistently generate maximum power from the PV system.

Under partial shading conditions, more than one peak can exist on the Power-Voltage (*P-V)* curve of a PV panel. In this situation, conventional MPPT methods like Perturb & Observe and Incremental Conductance may fail to track global peak. Convergence to local peaks may cause considerable loss in energy yield.

Effects of partial shadings on a PV array were investigated by simulations. Based on the results and observations, criteria to set minimum scan range have been suggested.

2. Effects of Partial Shading on PV Panel

2.1 Modeling of PV Panel

A solar cell also called as PV cell is an electrical device that directly converts solar energy into electrical energy. In this study, a single diode model of PV cell is considered [1].

$$I = I_{pv} - I_o \left[\exp\left(\frac{V + R_S I}{V_t a}\right) - 1 \right] - \frac{V + R_S I}{R_p} \quad (1)$$

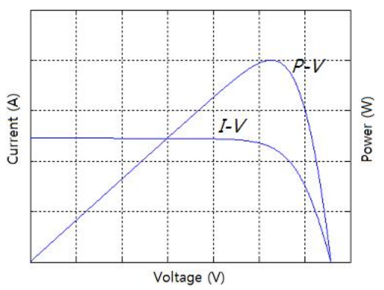


Fig. 1 .*I-V* and *P-V* characteristics of PV panel under uniform conditions

Fig. 1 shows the *I-V* and *P-V* characteristics obtained through simulations based on (1).A PV array consists of parallel-connected strings, in which several PV modules are connected in series, for higher voltage and current ratings.

2.2 Partial Shading

Under uniform irradiation on the PV array, the *P-V* curve of an array is unimodal, i.e. it has only one peak (Fig.1). Under partial shading, each PV module in the same string can be exposed to different irradiation (Fig. 2). The resulting *P-V* curve deviates from standard form in Fig. 1 and has multiple peaks due to bypass diodes. The effect of partial shading on *I-V* and *P-V* characteristics of a PV module are shown in Fig.3.

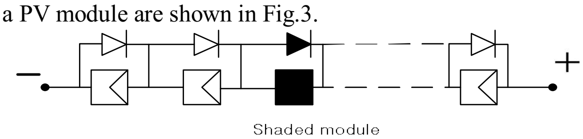


Fig.2. Shaded module in PV string

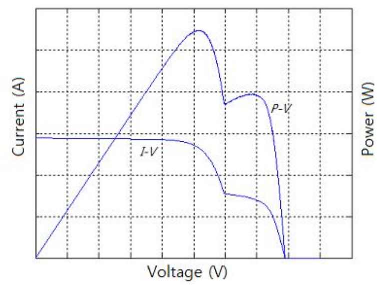


Fig.3. *I-V* and *P-V* characteristics of PV panel under partial shaded conditions

3. Tracking Strategy for Global MPP

3.1. Case Study for Partial Shadings

PV panels are subject to shading due to neighboring buildings or adjacent panels when the sun is ascending and descending[2].Such a shading situation is modeled and simulated as shown in Fig.4. Parameters of KC200GT PV module at (STC) 25 ℃ and 1000 W/m^2 are given in Table I.

Table I

System Parameters for Simulation

Parameters	Module	Array
Maximum Power	200 [W]	5000 [W]
Open Circuit Voltage	32.9 [V]	164.5 [V]
Short Circuit Current	8.21 [A]	41.05 [A]
Voltage at MPP	26.3 [V]	131.5 [V]
Current at MPP	7.61 [A]	38.05 [A]

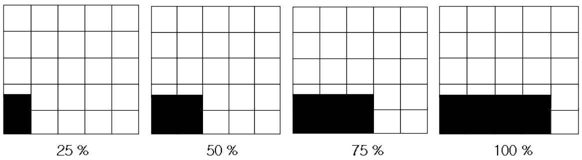


Fig. 4 .Particular shade pattern increasing with sun descent

As the sun descends, the shade increases and the global peak moves away from open circuit voltage of the PV array. PV characteristics for 100% case in Fig. 4 are shown in Fig.5.

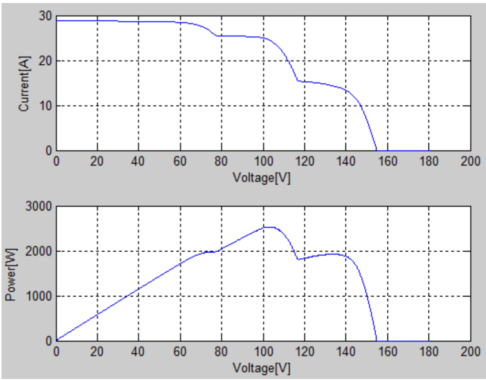


Fig.5. *I-V* and *P-V* characteristics of PV panel under 100% partial shaded conditions.

3.2. Efficient MPPT method

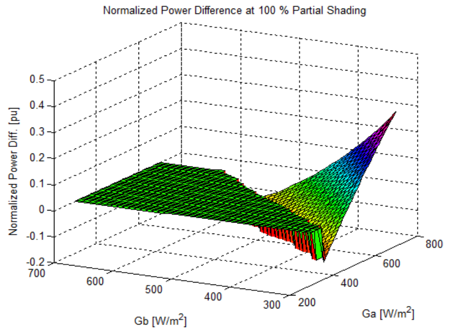
The conventional MPPT methods always starts from open circuit voltage of PV array since global peak is located close to the open circuit voltage when PV array is under uniform irradiation condition. After the first peak from the open circuit voltage is found by Incremental Conductance method, an additional scan may be not necessary to search for the other peaks. However, in partial shading condition shown in Fig.4, the scanning should be continued after finding the first peak from the open circuit voltage. In this case, the limit of the scanning range in horizontal axis in Fig.5 can be set based on the criteria that transient losses in the additional searching could be minimum. Also the scanning should be fast enough to satisfy the assumption that shade conditions are remained the same during the scanning process.

Voltage and power difference between the first peak and the second peak are dependent upon the shading pattern, i.e., shade percentage and the irradiance on the bright and dark parts of the PV array. By changing irradiation conditions on the bright and dark parts of PV array, the voltage and power differences between the peaks could be calculated through simulations. The normalized values of the voltage and power differences as function of irradiances of bright part (Ga) and dark part (Gb) for 100% shaded case are shown in Fig.6.

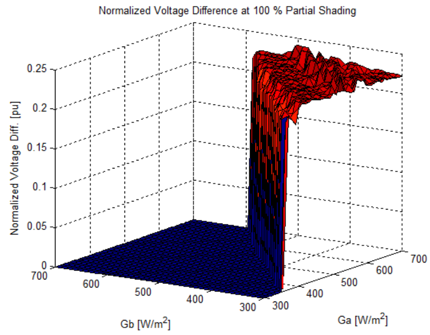
From Fig.6-b, it could be concluded that the second peak were mostly located around about 80% voltage of the first peak. Even though the maximum power at the second peak can be less or more than that at the first peak shown in Fig. 6-a, the unnecessary scanning can be prevented by limiting the scan range based on Fig. 6-b.

4. Simulation Results

To show the effectiveness of the scan range limitation, the conditions in Fig. 5 was assumed for MPPT simulations. In the case of Fig. 7-b, where the information in Fig. 6 was exploited, the search time evidently decreased compared with the case of Fig. 7-a. This is because unnecessary voltage points were skipped based on the information in Fig. 6. Furthermore, transient energy losses, which occur during the scan, could be minimized through limiting the scan range since the transient time was shortened.

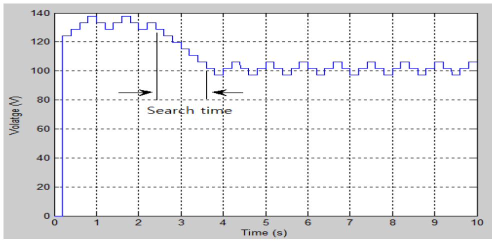


(a)

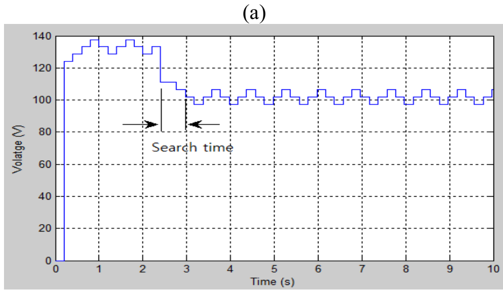


(b)

Fig.6.(a) Normalized power difference, (b) Normalized voltage difference *I-V* and *P-V* characteristics of PV panel under 100% partial shaded conditions defined as shown in Fig.4.



(a)



(b)

Fig.7. Reference voltage changes (a) without limiting the scan range (b) with limiting the scan range.

5. Conclusion

Effects of partial shadings on PV array have been studied. Criteria to set minimum scan range have been suggested. Based on these criteria, global peak can be found with minimum transient losses.

6. References

[1] M.G. Villalva, et al., "Comprehensive Approach to Modeling and Simulation of Photovoltaic Arrays", Power Electronics in Electric Utilities: Role of Power Electronics in Future Power System", IEEE Trans. On Power Electronics, Vol.24, No.5, May 2009

[2]. M. Garcia, et al. "Partial Shadowing, MPPT Performance and Inverter Configurations: Observations at Tracking PV Plants", Prog. Photovolt: Res. Appl. 2008; 16:529-536