Novel maximum power point tracking method for improving efficiency of photovoltaic generation system under partial shadow

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With the increment of installation density, the PV power generation system may encounter the external interference contributed by unpredictable variation of irradiance. Especially, the partial shadow, as one of main factors that lead to the problem of low conversion efficiency ought to be taken into consideration. This paper presents a novel maximum power point tracking method proposed in order to make sufficient utilization of solar energy, on the occasion when the photovoltaic modules are partially shaded. The novel method is based on Perturbation and Observation (P&O) method, with which the scan method is combined periodically. By using this method, the maximum power point can be checked out within transient period. For the purpose of verifying practicality of this novel method, simulation, as well as experiment have been carried out under the same circumstances, respectively. The consequences intuitively indicate that the conversion efficiency operated by proposed method is substantially improved under partial shadow.

Keywords : Conversion efficiency, Partial shadow, Photovoltaic generation system, Scan method

I. INTRODUCTION

I-A. General

Nowadays, with rapid development of renewable energy around the world, especially, the solar energy due to its features of neatness, reliability, sustainability is utilized widely,¹ which accounts for a large proportion from the configuration of renewable energy currently. Meanwhile, to maximize utilization of the solar energy, it is inevitable to make the increment of installation density of solar modules widespread, which may result in the consequence that

the stability of generation system can be disturbed more easily and frequently due to external conditions. Main severe factor is the partial shadow which is likely to be caused by cloud, leaves, plants and even the buildings around the households, particularly Photovoltaic(PV) generation station.²⁻⁴ The apparent influence contributed by partial shadow is low conversion efficiency. To overcome this generalized problem, in this paper, a novel maximum power point tracking (MPPT) control method has been proposed to improve conversion efficiency of PV generation system under partial shadow.

I-B. Theoretical basis

As introduced above, partial shadow caused by

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unstable external conditions derived of low conversion efficiency, which is the obstructive problem to be resolved. A representative example under consideration, is that when partial shadow occurs in the cell of panels as shown in Fig. 1. What can be easily found is that once the partial shadow occurs in the cell, the output power will decrease drastically. From the Fig. 2, the latest MPP (maximum power point) can only be tracked at a lower point, instead of the higher one.^{7, 8} As a result, the conversion efficiency of generation system is not so satisfactory at all. It is significant that a new MPP need to be checked out accurately on this occasion, when the partial shadow remains for long time.

Fig. 1. Configuration of PV modules.

Fig. 2. P-V characteristic under partial shadow.

II. PROPOSED METHOD

For the purpose of ascertaining a solution to the conventional problem discussed previously, the novel method proposed in this case is that the P&O method is treated as a basis, where the scan method is combined periodically.⁹ The improved algorithm is shown in Fig. 3. Within a consistently transient

interval during the period of operation, the scan method is adopted to check the optimal operating voltage by comparing the output power point from open state to short state, instantaneously. Therefore, the generation system can still operate at the optimal voltage controlled by P&O method to ensure the output power maximized as shown in Fig. 4 and Fig. 5. Meanwhile, the scan process is accomplished before the beginning of next new period.

Fig. 3. Flowchart of improved algorithm.

Fig. 4. Operation of improved algorithm.

Fig. 5. Diagram of proposed operation.

In order to prove the feasibility of the improved method, it is necessary to make the confirmation on both of simulation and experiment, respectively.

III. SIMULATION

In this section, the simulation environment is provided by PSIM, the simulator.

III-A. Simulation conditions

By using the simulator, the circuit of PV generation system is shown in Fig. 6. The main circuit consists of two solar panels, DC/DC converter and DC load.

Before carrying out a series of simulations, what needed to be done is to set the parameters of PV physical panels and simulated irradiance, respectively. Table 1 shows the specifications of one module. Aiming at making simulation under partial shadow, the input terminals called Lookup Table is utilized to create the irradiance, which are shown in Fig. 7.

Table 1. PV module specifications.

Parameters	Value
Maximum output	50[W]
Open-circuit voltage	20.5[V]
Short-circuit current	3.35[A]
Maximum operating voltage	16.4[V]
Maximum operating current	3.05[A]

Moreover, the role of DC-DC converter is to achieve the requirement for maximum power between different operating conditions using digital control element C block. The rest of elements of the circuit determined to be set as, the inductance of 7.5mH,

output capacitor of 660uF while other filter capacitors of 500uF. Constant voltage combined with adequately small resistance is treated as DC load under this circumstance.

(a)

(b)

Fig. 7. Simulation circuit of proposed; (a) Normal irradiance; (b) Abnormal irradiance under partial shadow.

Fig. 6. Simulation circuit of proposed.

III-B. Simulation results

The same conditions described above are applied to the simulation operated by two methods for output energy comparison of two panels, respectively. In particular, the scan method is operating in the proposed method after an interval with 25 seconds, whereas the simulation time is set to 200 seconds.

Fig. 8 indicates that the output power decline immediately with a drastic speed under partial shadow. Orange line shows the power reduction is suppressed when executing the proposed method. In addition, the amount of output energy of proposed method is almost 2Wh, while the conventional one is 1.3Wh, which shows the output of the former method is approximately 1.56 times of the later one. Therefore, it is confirmed that the proposed method is capable of operating at a new maximum power point to guarantee the output power maximized under partial shadow.

Fig. 8. Simulation results of output power.

IV. EXPERIMENTAL VERIFICATION

In order to further verify the practicality of this method, the experiment has been carried out under the same circumstance except for the scan period is set to 30 seconds. The results are shown in the Fig. 9 and Fig. 10. Fig. 9 demonstrates the detailed process of the

Fig. 9. I-V Characteristic of operation system.

improved method chosen within the range from 9:40:00 to 9:40:50. When partial shadow occurs in the panel, as circled by the oval, the current drops instantly, which contributes to severe decline of the output power. However, note that the output power is partially recovered by utilizing scan method to check a new maximum power point during the next scan period.

Fig. 10. Characteristic of output power.

And Fig. 11, it illustrates the solar radiation intensity of one day and the characteristics of the acquired power one day operated by both of the improved method and conventional method. The dot line represents the daily irradiance density. Similarly, orange line and blue line stand for the proposed method and conventional method, respectively. The amount of output energy of each panel generated by the former one is summed almost 159Wh, whereas the other one is 101Wh. It is observed that the amount of energy generated for one day by operating improved method is almost 1.57 times larger than the lower one. In summary, compared with the results provided by simulation, the actual conversion efficiency is nearly 1.6 times improved.

Fig. 11. Characteristics of output power for one day.

V. CONCLUSION

In this paper, a novel MPPT control method has been presented for improving the low conversion efficiency of PV generation system under partial shadow. The principle of this method can be described as that the conventional P&O method, in which an adequately transient scan period is combined to guarantee the real-time output power maximized by comparing the power point one after another. For the purpose of making verification of this method, both of simulation and experiment have been carried out, respectively. Compared to the conventional method, the results obtained indicate that the conversion efficiency of power generation system is greatly improved up to approximately 160% by using the novel one. In other words, the practicality of this novel method for improving the low efficiency under partial shadow is proved. Also, this proposed method may be employed for hot-spot detection in future study.

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