Study on Improvement of MPPT Efficiency in PV Generation System with Partial Shadow

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Abstract: The maximum power point of PV (photovoltaic) generation moves depending on weather conditions and load. Therefore, it is significant to make sure that the panels can work at the maximum power point under MPPT (maximum power point tracking) control. However, it has the problems of low efficiency and unstable operation when panels are covered by the partial shadow. The result is that the output power may be substantially decreased. To overcome this issue, the authors propose a new plug-in operation point correction system. This system is put between PV panels and PCS (power conditioning system) in the existing PV generation system. In this paper, the experimental results describe that the output electric energy increases approximately 1.4 times as compared with the conventional system when the proposed correction system is inserted.

Key words: PV generation system, operation point correction, MPPT, partial shadow.

1. Introduction

The maximum power point of PV generation moves depending on weather conditions and load. Therefore, it is significant to make sure that the panels can work at the maximum power point under MPPT (maximum power point tracking) control [1-4].

However, it has the problems of low efficiency and unstable operation when panels are covered by the partial shadow. The result is that the output power may be substantially decreased. In order to solve this problem, the authors proposed new algorithm which detects maximum power point, scanning the I-V characteristics [5-10]. As this method is mounted into the PCS (power conditioning system), it is suitable for new installation of PV generation system.

This paper proposes a new plug-in operation point correction system which corrects the operating point of PV panels in the existing PV generation system [11-13].

2. Outline of Conventional PV Generation System

Fig. 1 shows the configuration diagram of the conventional PV generation system. The output voltage of PV panels is applied to the PCS input. The applied DC voltage is converted to the AC voltage as an output voltage of the PCS. The PCS output is connected to the power grid. The PCS has two main functions. One is "MPPT function", the other one is "inverter function". In the PCS, the P&O method is normally used as MPPT algorithm.

Fig. 2 shows the P-V characteristic (without shadow & with shadow). In the PV generation system with a shadow, because of the function of the bypass diode, two or more peaks occur in the P-V characteristic, as shown in the figure. The P&O method may operate at a lower peak point voltage when there are two peaks in the P-V characteristic as shown in Fig. 2. This is a problem of the conventional MPPT method.

3. Proposed PV Generation System

The system configuration diagram of proposed system is shown in Fig. 3. By inserting an operation

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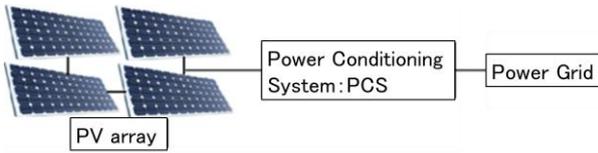
Fig. 1   Configuration diagram of conventional PV system.
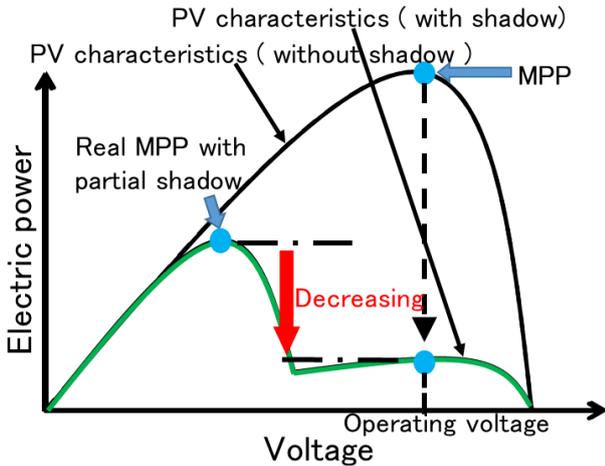
Fig. 2   P-V characteristic (without shadow & with shadow).
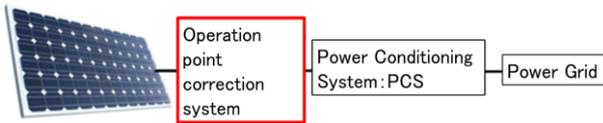
Fig. 3   Configuration diagram of new plug-in operation point correction system.
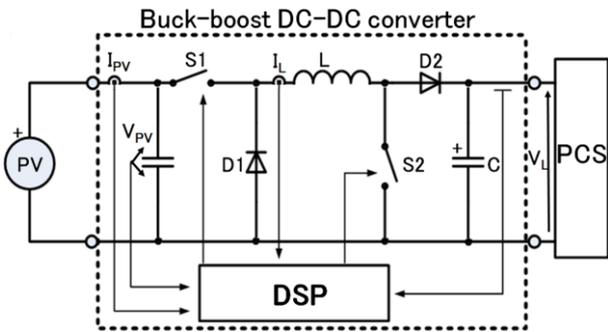
Fig. 4   System configuration.

point correction system between panel and PCS, it becomes possible that the PV generation system covered by partial shadows can operate at the maximum power point through the P&O method of the PCS. Fig. 4 shows the configuration diagram of the developed operation point correction system. This developed system is the section enclosed in the dotted line and it consists of a buck-boost type DC-DC converter.

The operating voltage of the PCS has an operable

range. It is necessary to distinguish the operation depending on whether V_{OP} at the maximum power point is within the PCS operable range (pattern A) or out of the range (pattern B).

3.1 Concept of Operation at Pattern A

V_{Lmin} is the lowest value of range of the PCS input operating voltage. Pattern A is in the case that V_{OP} is V_{Lmin} or more. Fig. 5 shows a conceptual diagram of operation in the case of pattern A, where there are two peaks in the P-V characteristic. This system generates the output power along with the arrow (red dotted line) and directs the operating point voltage V_L to the maximum power point voltage V_{OP} (bridge operation). In other words, this system only supports the MPPT of the PCS.

3.2 Concept of Operation at Pattern B

Fig. 6 shows the operation conceptual diagram of pattern B (V_{OP} is less than V_L). In this case, the maximum power point voltage V_{OP} is out of the range of the PCS input operating voltage. The maximum power point P_{MAX} can be moved into the operable range by using switching control with a DC-DC converter, which performs boost operation with a constant step-up ratio n. The step-up ratio n is,

$$n = V_L / V_{OP} \tag{1}$$

Proposed system in pattern B always boosts the operating point voltage, and proposed system performs MPPT with P&O method of the PCS.
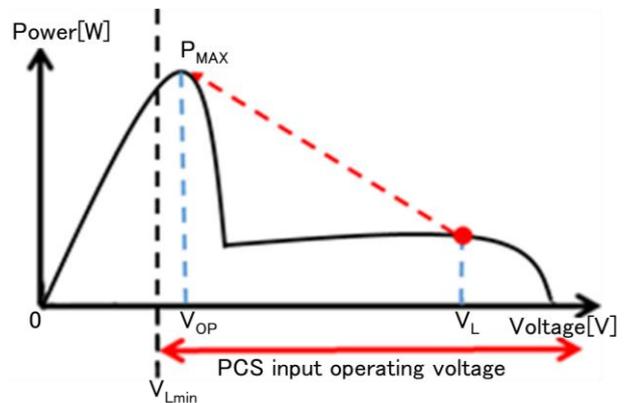
Fig. 5   Conceptual diagram of pattern A.
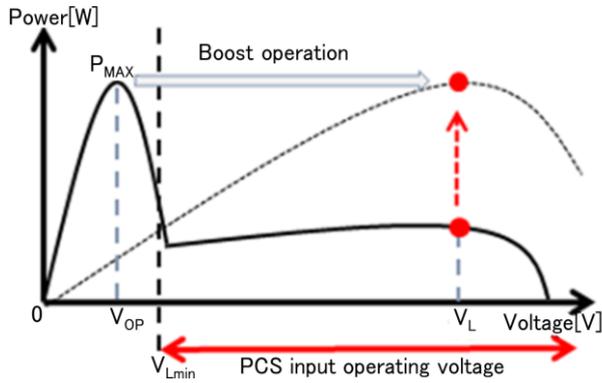
Fig. 6   Conceptual diagram of pattern B.
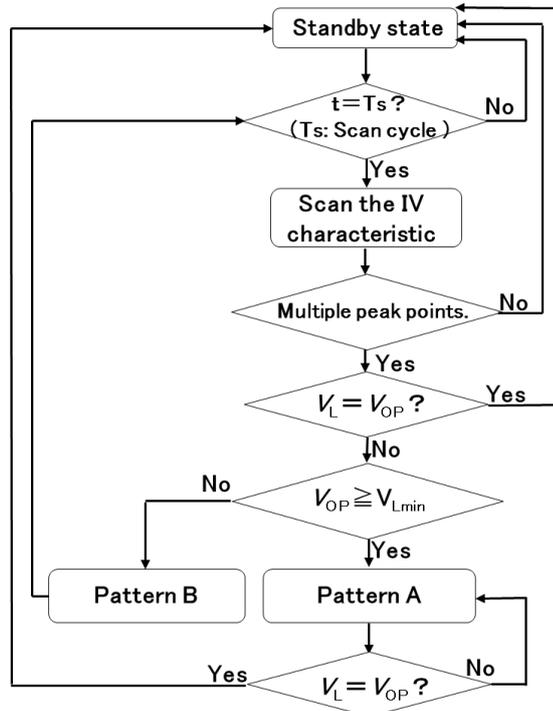
Fig. 7   Flowchart of the proposed system.

Fig. 7 shows the flowchart of the proposed system. In the standby mode, the output of PV panels is sent directly to the PCS. Next, when $t = T_s$ (scan cycle), the proposed system scans the *I-V* characteristics to detect V_{OP} and makes a comparison with V_L. And, the system confirms whether the multiple peak points exist. When V_L is equal to V_{OP}, the correction system returns to standby mode. If V_L is not equal to V_{OP}, the system compares V_{OP} and V_{Lmin}.

When V_{OP} is V_L or more, the proposed system operates on pattern A. When V_L equals to V_{OP}, the correction system returns to standby mode. When V_{OP}

is less than V_L, the proposed system operates on pattern B. Using the step-up ratio n calculated by Eq. (1), the converter achieves the step-up operation.

4. Experimental Results

4.1 Operation Confirmation Experiment

Fig. 8 shows the experimental circuit. In this experiment, PV simulator is used instead of PV panels, and P&O unit is used instead of PCS.

Table 1 shows the specifications of PV simulator. *I-V* characteristics are able to change for solar radiation intensity. Operation point correction system is placed between PV simulator and P&O unit.

Fig. 9 shows the *P-V* characteristics of the PV simulator considering the partial shadow. The V_{OP} of the PV simulator is about 15 V.
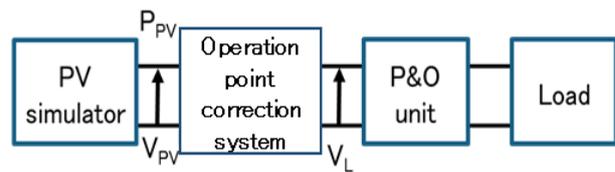
Fig. 8   Experimental circuit.

Table 1   Specifications of PV simulator.

Maximum output P_{MAX}	91.6 W
Open circuit voltage V_{OC}	38.7 V
Short circuit current I_{SC}	3.67 A
Voltage at maximum output V_{OP}	28.2 V
Current at maximum output I_{OP}	3.25 A
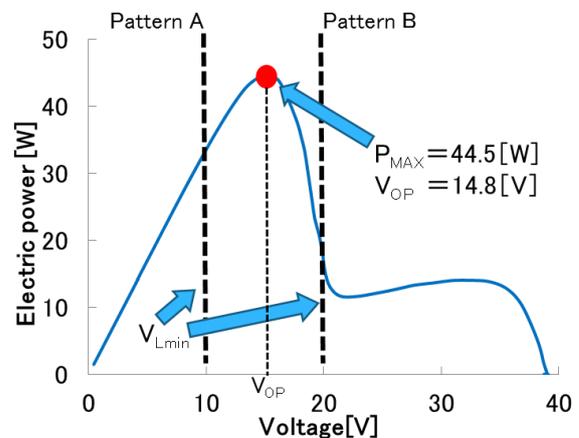
Fig. 9   *P-V* characteristic of PV simulator considering the partial shadow.

In this P-V characteristic, if V_{Lmin} is set to 10 V then the system condition is in pattern A. And if V_{Lmin} is set to 20 V then the system condition is in pattern B.

Fig. 10 shows the experimental result when V_{Lmin} is 10 V. It is confirmed that the PV simulator output voltage V_{PV} is correctly moved to the V_{OP}. This is the bridge operation mode. P_{PV} increases to 40 W by this operation. After the bridge operation mode, the system mode transits the standby state mode. As a result, it is confirmed that the proposed system operates correctly.

Fig. 11 shows the experimental results when V_{Lmin} is 20 V. The input voltage V_{PV} of 15 V which is out of the operation range of PCS, is boosted to 30 V as the output voltage V_L. P_{PV} increases to 40 W by this operation. It is confirmed that the PV simulator output voltage V_{PV} moves correctly to the V_{OP}. As a result, it is made clear that the proposed system operates correctly.

4.2 Main Experiment

The effectiveness of proposed system can be evaluated by the amount of electric energy and operating voltage measured from input and output of the proposed system, comparing between the conventional system and the proposed system. As shown in Fig. 12, 2 PV panels are connected in series, and about 3/4 shadow is added to one cell from 9:00 am. The minimum operating voltage V_{Lmin} of PCS is set to 10 V.

Fig. 13 shows P-V characteristic with partial shadow. Furthermore, the optimum operating voltage V_{OP} of the PV panel is about 23 V after 9:00 am.

In this case, experimental condition is in pattern A. Table 2 shows the specifications of the PV panel.

Fig. 14 compares the acquired electrical power from the panels between the proposed system and conventional system. This figure shows an increase in the acquired electrical power when the proposed system is used. The generated electrical energy with conventional system is 318 Wh, the generated electrical energy with the proposed system shows an increase to 456 Wh. Therefore the generated electrical

energy of daytime is 1.4 times increased as compared with the conventional system.
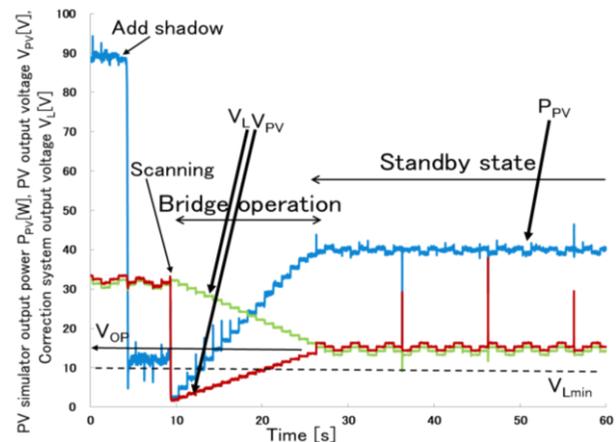
Fig. 10   When V_{Lmin} is 10 V.
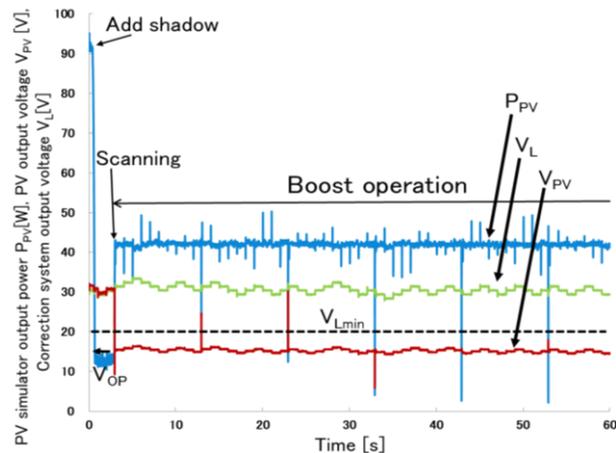
Fig. 11   When V_{Lmin} is 20 V.
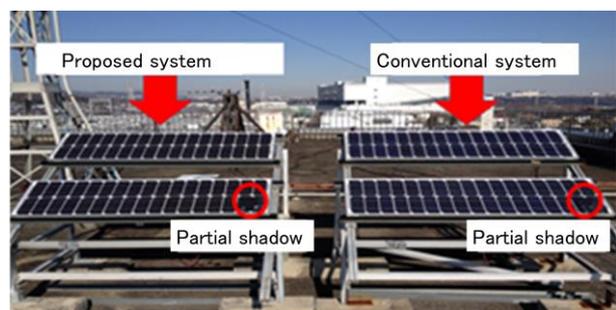
Fig. 12   Experimental landscape.

Table 2   Specifications of the PV module.

Maximum output P_{MAX}	50 W
Open circuit voltage V_{OC}	20.5 V
Short circuit current I_{SC}	3.35 A
Voltage at maximum output V_{OP}	16.4 V
Current at maximum output I_{OP}	3.05 A
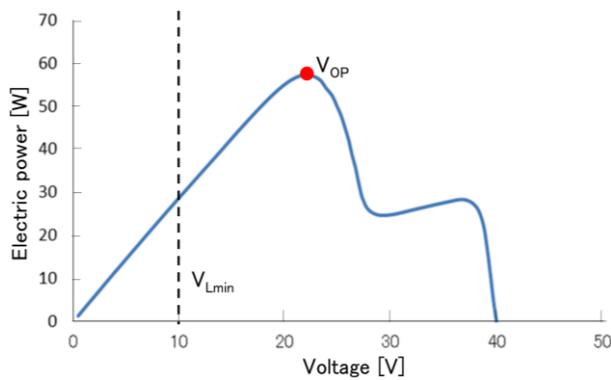
Fig. 13   *P-V* characteristic with partial shadow.
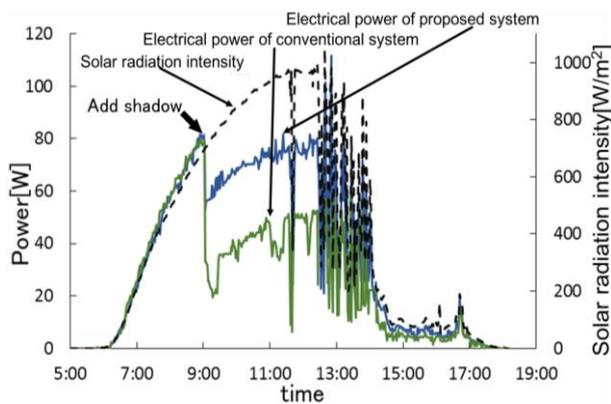
Fig. 14   PV output power characteristics.
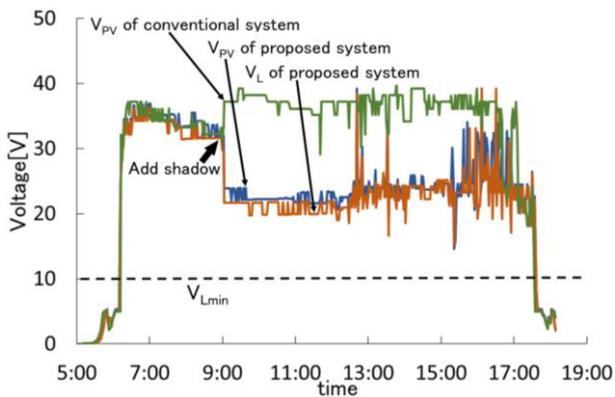
Fig. 15   The operating voltage comparison.

Furthermore, corrected time zone of the proposed system is from 9:00 am to 5:00 pm. In this time zone, the generated electrical energy with conventional system is 198 Wh, the generated electrical energy with the proposed system is 341 Wh. Therefore the generated electrical energy is 1.7 times increased by using the proposed system from 9:00 am to 5:00 pm.

Fig. 15 compares the proposed system operating voltage with conventional system operating voltage

V_{PV}. In the conventional system, it is confirmed that the partial shadow is added, the operating point voltage V_{PV} does not go to V_{OP}. However, in the proposed system, the operating point voltage V_{PV} is corrected to V_{OP} after the shadow addition. As a result, it is confirmed that the PV panels operate at the maximum power point by using the proposed system.

5. Conclusions

From these experimental results, it is confirmed that the proposed system operates correctly and the maximum power point is obtained by the PCS. In addition, it is clarified that by using this system when there is a partial shadow, the amount of generated electric energy under the present experimental conditions increases approximately 1.4 times, as compared with the conventional system.

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