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An Improved Global Maximum Power Point Tracking Scheme under Partial Shading Conditions

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Abstract – A photovoltaic array exhibits several local and single global maximum power points under partial shading conditions. To track the global maximum power point precisely, a novel global maximum power point tracking scheme is proposed in this paper. In the proposed scheme, robustness of the tracking performance has been improved by enhancing searching profile. In addition, the paper addresses the tracking failure condition, and provides the experimental verification with several simulation and experimental results.

Keywords: Maximum power point tracking, Partial shading Conditions, Photovoltaic Array

1. Introduction

The maximum power point tracking (MPPT) algorithm is essential to operate a photovoltaic (PV) system under a maximum power point (MPP) with variable power-to-voltage (P-V) characteristics, which depends on temperature, insulation, or nonlinearity of a PV. In addition, several MPPs occur on the P-V curve under partially shaded condition. To overcome this phenomenon, several global MPPT algorithms have been proposed and implemented to find the global MPP from the PV characteristics.

Many global MPPT algorithms purse the optimal operating point on the basis of an observation approach by sweeping overall P-V characteristics [1]. These algorithms have advantages of effectiveness such as fast global MPP tracking time and stable PV voltage movement. But they sometimes fail to track the global MPP, especially when one of local MPPs exists among two higher MPPs, where one of them is the global MPP, as shown in Fig. 1.

This paper discusses this failure mechanism and proposes an improved global MPPT scheme in order to avoid the failure and thus improve a searching performance. The proposed scheme also adapts observation approach, similar to conventional algorithm, and thus shows similar advantages of the conventional algorithms. But it improves precise global MPP tracking capability under partially shaded conditions. To verify the effectiveness of the improvement, several simulation and experimental results are provided.

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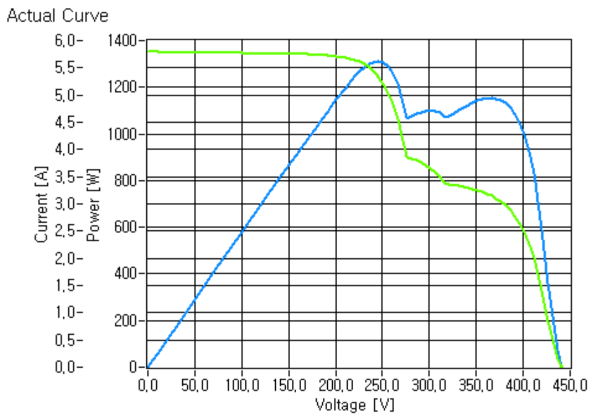


Fig. 1. Typical photovoltaic I-V characteristics under partial shading condition.

2. Proposed Global MPPT Algorithm

The tracking failure of conventional global MPPT algorithms results from their operation principle. Fig. 2 shows operational flowchart of the previously proposed global MPPT. The scheme consists of three subroutines, main program, timer interrupt subroutine, and global MPP tracking subroutine. In the main program, general MPP algorithm performs a perturbation and observation method to find the MPP until partial shading conditions are detected. After detecting partial shading conditions, the main program calls the timer interrupt subroutine. The timer interrupt subroutine invokes the global MPP tracking subroutine periodically under a prefixed time interval and the global MPP tracking subroutine sweeps existing MPP in some ranges of a photovoltaic characteristics and identifies the global MPP among several detected MPPs.

The global MPP tracking subroutine consists of basic four steps as follows: 1) PV voltage is moved from the initial operating point by step of 60~70% of Voc of PV module. 2) After every movement of PV voltage, dP/dV is calculated to search the local MPP in vicinity of current PV voltage. 3) The MPP is tracked by P&O algorithms. 4) If the power corresponding to tracked MPP is larger than the previous MPP, the information of this MPP is stored.

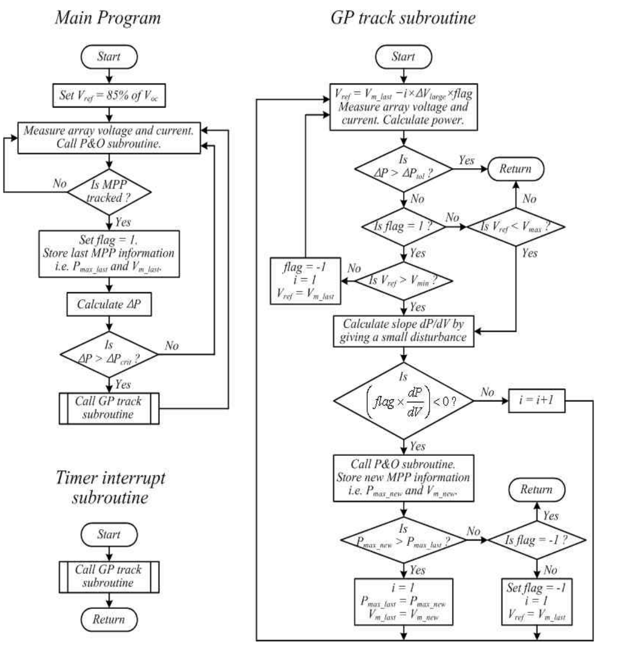


Fig. 2. Operational flowchart of conventional global MPPT algorithm.

These four steps are repeated in the both direction following the x-axis of the characteristic curve, which is usually defined as generated voltage of photovoltaic. In the beginning of the global MPP tracking subroutine, default direction is set to the way to decrease the output voltage. Once the output voltage reach the predefined lower limit, then the direction becomes opposite and thus output voltage starts to increase until the smaller MPP than the previous detected MPPs during a decreasing direction is detected. When the smaller MPP is found, the global MPP subroutine is finished and the conventional algorithm returns to the main program. The operation of the conventional MPPT algorithms, which stops when the smaller MPP is found, leads to failure of track the global MPP under some partial shading condition, which results the I-V characteristic of Fig. 1 because, in the forth step, observation stops at a local MPP and doesn't progress further to find the real global MPP.

To overcome this situation, the proposed MPPT algorithm scans entire range of MPPT of the system. The operation which finishes GP track subroutine when smaller MPP is found is modified to move the operating point in current direction and search other MPPs until PV voltage reaches lower limit or upper limit. If PV voltage reaches lower limit, the direction is changed to increase PV voltage from initial operating point. If PV voltage reaches upper limit, operating point moves to the largest MPP and the algorithm is tracked and GP track subroutine finishes. Fig. 3 shows the operational flowchart of proposed global MPPT algorithm and it can find the global MPP on the every P-V curve under partially shaded conditions by scanning entire MPPT range and comparing all MPPs on the P-V curve.

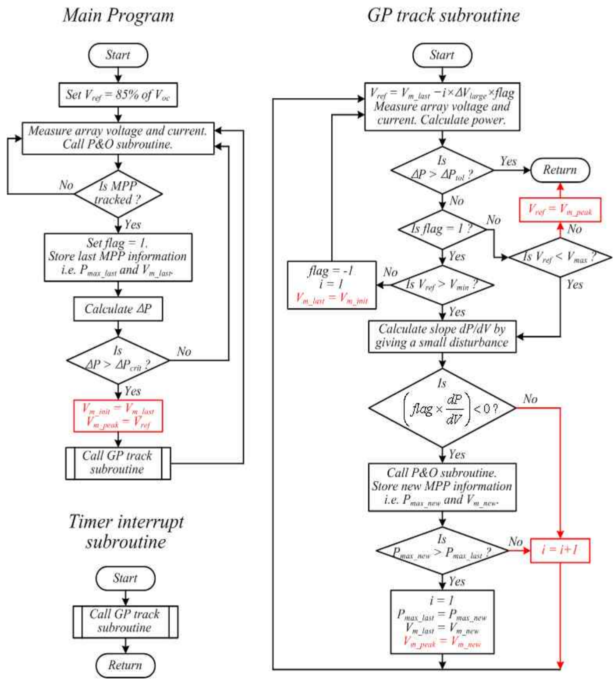
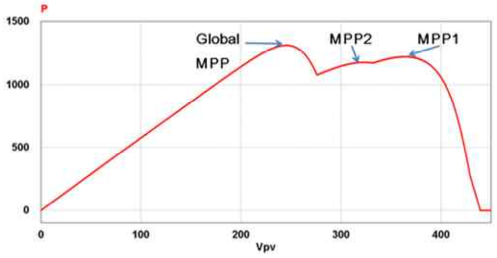


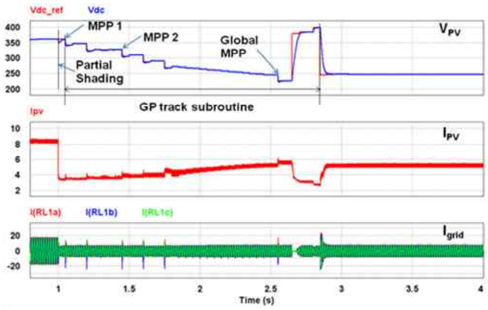
Fig. 3. Flowchart of proposed global MPPT algorithm.

3. Simulation Result

The proposed MPPT algorithm was simulated on the PV curve of Fig. 4(a). The existing MPPT algorithm fails on this curve. Fig. 4(b) is the result. The initial operating point is at the MPP 1. After one sample time from partial shading, GP track subroutine starts. MPP 2 and Global MPP are detected while the PV voltage decreases. P&O algorithm tracks local MPPs in the interval which PV voltage decreases gradually. When the PV voltage reaches the lower limit, the algorithm changes direction and tracks the MPPs from the initial operating point in the direction of increasing PV voltage. When the PV voltage reaches the upper limit, GP track subroutine finishes and the operating point is moved to the global MPP.



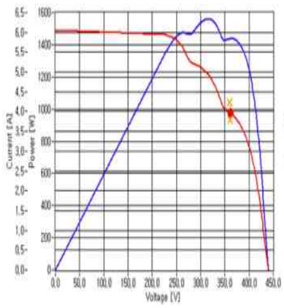
(a)



(b)

Fig. 4. Simulation results of proposed global MPPT algorithm.

4. Experimental Result



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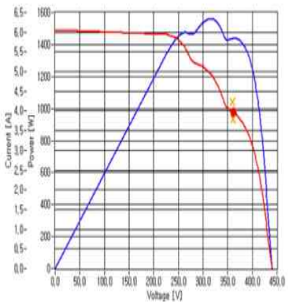

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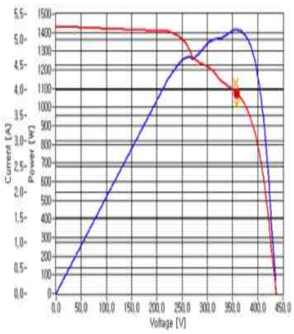

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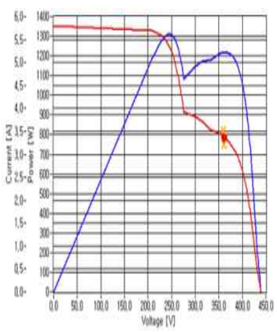
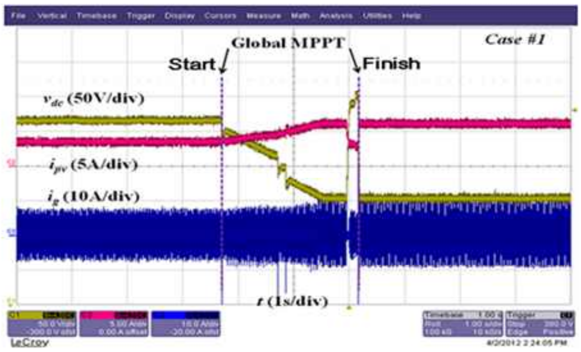


(d)

Fig. 5. Several cases of photovoltaic characteristics under partial shading condition.



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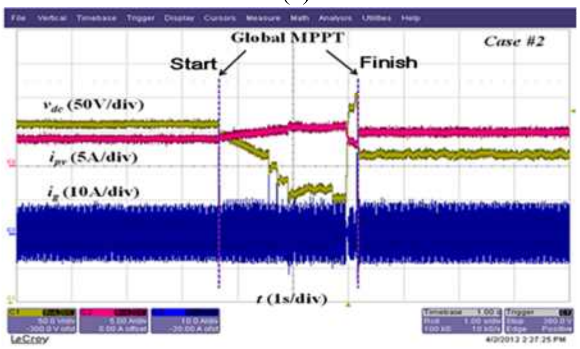

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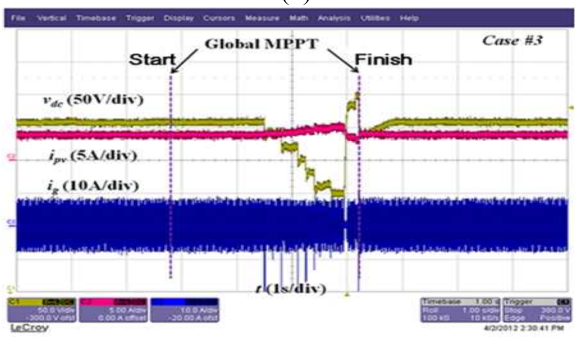

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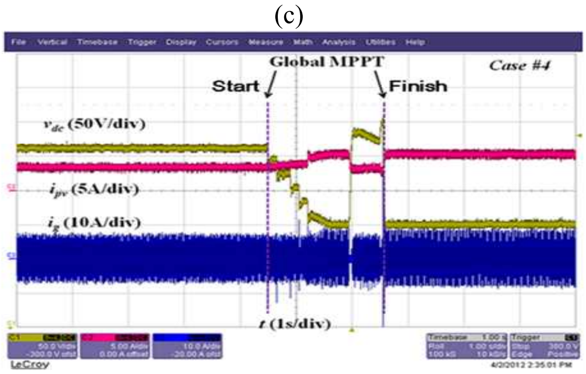

(d)

Fig. 6. Experimental results of the proposed global MPP tracking algorithm.

The proposed MPPT algorithm demonstrates on the grid connected 3 phase inverter connected to PV simulator. Assuming the partially shaded conditions, the algorithm tracks the global MPP on 4 types of P-V curve. Fig. 5

shows four P-V curves and the operating points before the global MPP tracking subroutine start. Once the GP track subroutine starts, PV voltage decreases from the initial operating point to lower limitation (225V), then increases from the initial operating point to upper limitation (400V). When the global MPP tracking subroutine finishes, the operating point moves to global MPP. Especially, proposed MPPT also tracks the global MPP on the fourth P-V curve which the existing MPPP fails.

5. Conclusion

This paper presents the existing MPPT algorithm fails to track the global MPP where the small MPP locates between two larger MPPs and the initial operating point is at one of the two larger MPP like Fig. 1 and the cause is that the MPPT scheme scans P-V curve until the MPP which has smaller power than previous MPP is found in the direction of scan.

The improved MPPT algorithm which scans the entire range of PV voltage of the system has been proposed to track the global MPP on the every type of P-V curve under partially shaded conditions. And the simulation and the experimental results on 4 types of P-V curve have been presented to demonstrate the proposed MPPT algorithm.

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