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GLOBAL MAXIMUM POWER POINT TRACKING UNDER PARTIAL SHADING CONDITION USING MODIFIED SEPIC CONVERTER

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ABSTRACT

Tracking of maximum power point (MPP) is an inevitable part of a system of energy conversion using photovoltaic (PV) array. Under uniform solar irradiance the popular conventional maximum power point tracking algorithms are effective. However, under solar irradiance mismatching conditions (partially shaded conditions (PSCs)) defects the current-voltage and power-voltage characteristics of photovoltaic system significantly. Especially partial shaded phenomenon affects the power-voltage characteristics because it contains multiple peaks and steps. So, the conventional tracking algorithms fails to guarantee successful tracking of the real MPP (Global Peak (GP)), and it tend to stay in local peak power point which considerably reduce the energy and efficiency of the PV system. In this paper, a new algorithm called improved hill climbing algorithm is used to track the global peak power from PV array under partially shaded condition and modified SEPIC converter is used as a DC-DC interface. The performance of proposed maximum power point tracking (MPPT) is analyzed and verified by simulations with the help of MATLAB/SIMULINK.

Key words: Maximum power point tracking (MPPT), Hill climbing algorithm, Photovoltaic I-V characteristics, Global Maximum Power Point (GMPP)

I. INTRODUCTION

The environmental issues motivate the world towards the development of renewable energy. The sunlight is the major source of renewable energy and the photovoltaic cells are operated by the influence of the solar irradiation, shading and temperature. Through PV effect directly it converts the energy of solar light into the electrical energy. But the predicament associated with this energy conversion is the tracking of maximum power point. When the entire array does not receive identical irradiation (i.e. partially shaded conditions) then the power to voltage characteristics curve become more complex and it contain multiple numbers of peaks and steps. This reduces the effectiveness of the existing maximum power point schemes due to their inability to differentiate between the local peaks and global peak [5]. A partial shading condition (PSC) occurs due to trees, buildings, or clouds and it is quite common. So, it is very necessary to improve power and efficiency of the PV. But under PSC, conventional MPP tracking algorithms such as hill climbing algorithm, perturbation and observation algorithm, and incremental conductance algorithm may not be able to track maximum power irrespective of the change in irradiance conditions. It may converge at the local maximum power point (LMPP) resulting in reduction of PV panel output power and efficiency. So, it is indispensable to develop a special MPPT algorithm that can track the global MPP under PSC. This paper proposes a special algorithm called improved hill climbing algorithm to track the global peak under PSC to improve the PV power and efficiency and modified SEPIC converter used as a DC-DC converter.

In [1], MPPT technique anticipated is based on particle swarm optimization (PSO). This method performs effectively under various mismatching conditions. The main drawback of this method is that the PSO technique contains many variables and it can be set only by the engineer. So, an uncomplicated solution is the sweeping search by Hill climbing algorithm across full operating voltage with sufficiently dense searching which often leads to long search time. In [2], MPPT based on P & O algorithm with global peak (GP) subroutine is proposed to track the maximum power. Despite the fact that it does not necessitate any additional circuit, it guarantees tracking the global power peak only when multiple peak power points occur to be on the same power levels. In [3], MPPT is processed by using the modified Hill climbing algorithm, large change in duty cycle (D) is used to carry out global searching, D is just to find out dissimilar peak power points developing on the P-V characteristics of the PV array and then small change in duty cycle is used for local searching, D only in the region of Global maximum peak power so that search time is significantly abridged. In [4], it consists of a two-stage MPPT along with Voc and Isc measurements is proposed. Even if it is very simple to apply, extra circuits are necessary to measure Voc and Isc.

II. SYSTEM STRUCTURE

This section provides the modeling of PV system and design of the converter with MPPT.

A. description of basic block diagram:

Basic block diagram of PV maximum power point tracking system implemented using Modified SEPIC converter is shown Fig. 1.

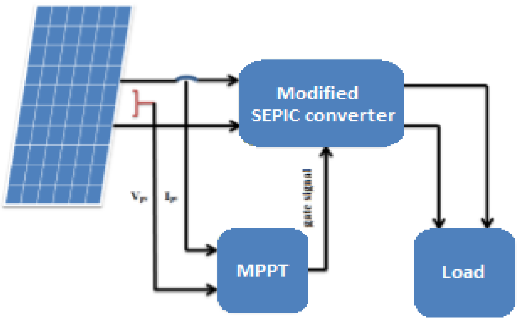

Fig. 1. Block diagram of the proposed system

The Modified SEPIC converter is used as the load which is supplied from the series connected three PV modules. Extracting the maximum power from the PV module is done with the help of MPPT controller and the voltage Vpv current Ipv is given as the input to the MPPT controller. By controlling the duty cycle (D) along with the help of MPPT controller is used to implement the global MPPT algorithm.

B. modified SEPIC converter:

A modified SEPIC converter is the new form of SEPIC converter to get a high static gain and step-up output. For that in the basic SEPIC converter a multiplier diode and multiplier capacitor is added. The voltage multiplier technique is used to increase the static gain of single-phase and multiphase boost dc–dc converters [6,7]. An adaptation of the voltage multiplier technique with the SEPIC converter is shown below

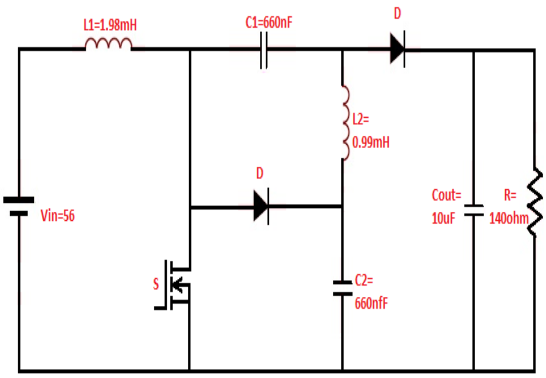

Fig. 2. Modified SEPIC converter

The following equations are used to design the SEPIC converter.

(1) Duty cycle:

$$D = \frac{(Vo - Vin)}{(Vo + Vin)}$$

(2)The inductor value is calculated by:

$$\Delta il1 = \frac{Vi \times D}{L1 \times f}$$

$$L1 = \frac{Vi \times D}{f \times \Delta il1}$$

$$L2 = \frac{L1}{2}$$

(3) coupling capacitors:

$$C1 = C2 = \frac{il2 \times D}{\Delta Vc \times f}$$

(4) Selection of Output capacitor:

$$Cout = \frac{Iout \times D}{\Delta Vo \times 0.5 \times f}$$

(5) Output current:

$$Iout = \frac{Vo}{R}$$

(6) Resistance value:

$$R = \frac{Vo^2}{P}$$

TABLE I SPECIFICATION OF MODIFIED SEPIC CONVERTER

PARAMETER	VALUE	UNIT
V_{in}	56	V
V_o	112	V
f_s	30	KHZ
L_1	1.98	mH
L_2	0.99	mH
C_1, C_2	660	nF
C_{out}	10	µF
Power	90	W

III. PV MODELING UNDER PARTIAL SHADING:

In this paper three PV modules are connected in series with by-pass diodes and negligible capacitances. The by-pass diode is used to reduce the damages during the change in irradiances. The PV model is taken from the PSIM 9.0.3 version is shown in fig. 3 and the datasheet is provided in table 2

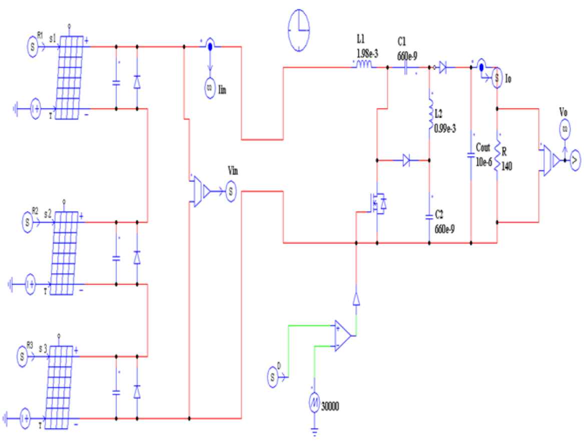

Fig. 3. The model of modified SEPIC converter

TABLE II Datasheet parameter values of the pv module

Parameter	Symbol	Value	Unit
Open circuit voltage	Voc	66.6	V
Short circuit current	Isc	1.73	A
Maximum power voltage	Vmp	55.2	V
Maximum power current	Imp	1.63	A
Maximum Output power	Pmax	90	W

IV. BEHAVIOUR OF PV ARRAY UNDER PARTIALLY SHADED CONDITIONS

In PV array the PV modules are connected either in series or parallel combination. Bypass diodes and blocking diodes are connected in parallel and series to the PV module to protect modules from the hotspot and effect of potential difference between series connected strings respectively. Under uniform solar irradiance condition, there exists only one MPP on the P-V characteristic curve. On contrary, under non-uniform irradiation (partial shading) conditions, several local maximum power points develop on the P-V characteristic curve because of bypass and blocking diodes. Using MATLAB/SIMULINK software the varies non-uniform shading conditions of the PV array are tested. Fig. 4 shows the P-V characteristic of a partially shaded PV array when they receive the irradiation as S1=800, S2=200, S3=800 from top to bottom with respect to Fig. 3. Similarly Fig. 5 and Fig. 6 show P-V5 characteristic curve for S1=1000, S2= 800, S3=600 and S1=800, S2=200, S3=600 irradiations respectively.

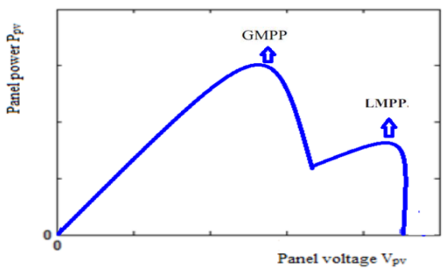

Fig. 4. S1=800 W/m^2,S2=200 W/m^2,S3=800 W/m^2

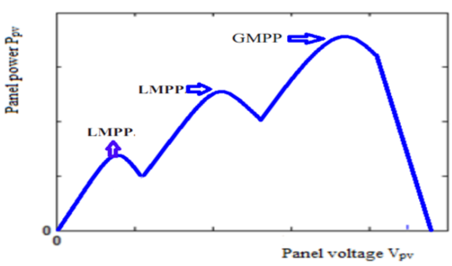

Fig. 5. S1=1000 W/m^2,S2=800 W/m^2,S3=600 W/m^2

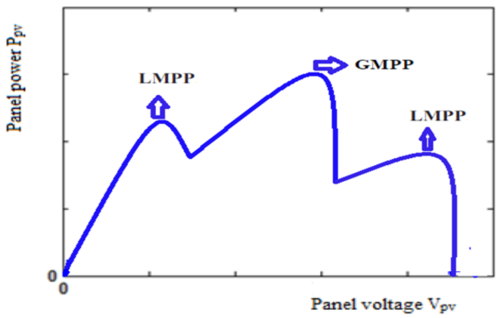

Fig. 6. S1=800 W/m^2,S2=200 W/m^2,S3=600 W/m^2

Fig.4, fig.5 and fig.6 show that there are several peaks that exist on the P-V curve. In fig.4, global MPP occurs at a low voltage level and the local MPP occurs at a voltage quite close to that one at which the unique MPP normally occurs. In fig.5, the global MPP occurs at a voltage quite close to that one at which the unique MPP normally occurs in the uniform irradiation case. In fig.6, global MPP occurs at middle voltage level. This global MPP happens to be in between two local MPPs. Hence, partial shading has a strong impact on the P-V characteristic curve of the PV system. Therefore, a conventional MPPT technique settles at a local MPP which exist around almost 75% of Voc which may not be the global MPP as shown in the figures 4 and 5. As a result, efficiency of the system is significantly reduced. Hence, global MPP tracking techniques are required to improve the performance of the PV array.

V. PROPOSED GLOBAL MPPT ALGORITHM

Conventional global MPPT algorithms fail to track global MPP under partial shading condition as a result of their operation principle. Therefore the proposed algorithm has been developed to work in such a way that it tracks global MPP under any partial shading condition.

The proposed algorithm consists of two stages mainly

- Perturb and observe algorithm during steady weather condition.
- Global MPPT algorithm during changing steady weather condition.

Global MPPT algorithm in turn consists of two sub stages namely

- Global search with a large step size Δd.
- Local search with a small step size Δd in the region of global MPP.

Under almost constant weather conditions, P&O algorithm keep the operating point around GMPP which was detected by GMPPT algorithm.

At first, GMPPT algorithm tracks the GMPP among the several defected MPP's by executing global search with large step size in Δd. The search in carried out along the P-V characteristics with lower and upper limits fixed on the x-axis voltage which corresponds to duty cycle Dstart and Dend respectively. During global search, change in power at instant ΔP(k)=P(k)-P(k-1) is computed and hence all MPPs are detected by observing sign change of ΔP(k) from positive to negative. Each MPP with corresponding power P(k-1) and duty cycle d(k-1) are stored. Once the global search is finished, then comparison is done among the several MPPs to single out the global MPP with corresponding duty cycle.

Now, operating point on the P-V characteristics is moved to global MPP by having large Δd. Since large step size Δd was used in global search, global MPP identified is only near the actual global MPP. Hence, local search is initiated with very small Δd to capture the exact GMPP.

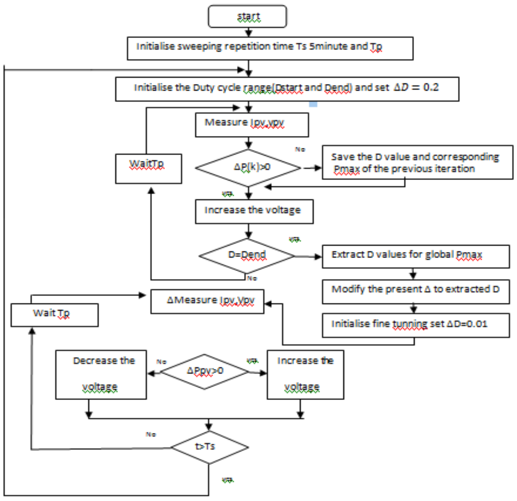

Fig. 7. Flowchart for GMPPT algorithm

VI. Simulation Results and Discussion

Simulation of the proposed system has been executed in MATLAB/SIMULINK environment coupled to PSIM through simcoupler module. Program has been written in MATLAB environment for implementing the hill climbing algorithm and simulation of modified SEPIC converter with PV array has been executed in PSIM coupled with SIMULINK.

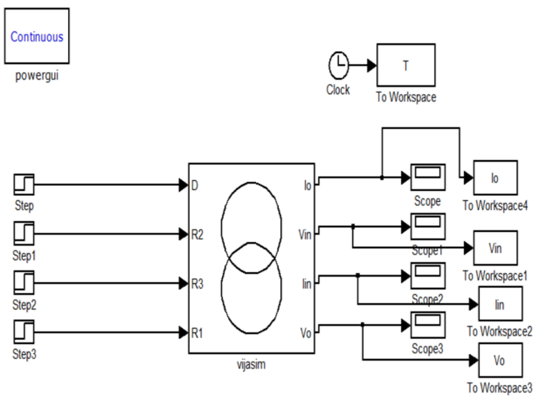

Fig. 8. Simcoupler Module linked to PSIM environment

Three different patterns of partial shading conditions as described in table3 have been simulated and the results are shown in the fig. 9, fig.10 and fig.11.

TABLE III PATTERNS OF PARTIAL SHADING CONDITIONS ON SOLAR PANELS

	Panel 1 (TOP) (W/m²)	Pane 2 (W/m²)	Pane l3 (BOTTOM) (W/m²)
Pattern I	800	200	800
Pattern II	800	200	600
Pattern III	1000	800	600

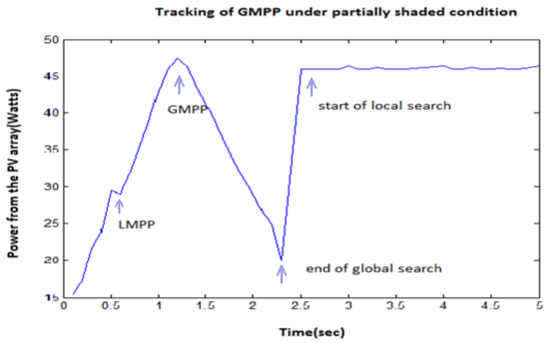

Fig. 9. Tracking of GMPP for pattern I

P-V curve of the PV array has been simulated for pattern I and shown in fig. 9. The result shows that there is one local MPP and one global MPP on the PV characteristics. The GMPP technique proposed in this paper identified global MPP through global search and has settled at the GMPP through local search at steady state.

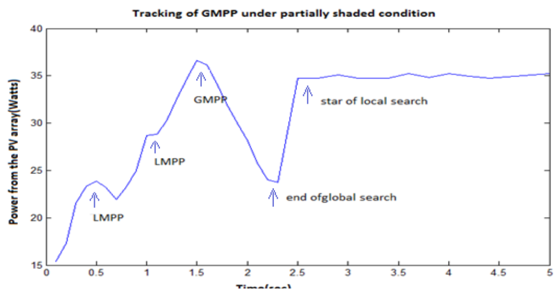

Fig. 10. Tracking of GMPP for pattern II

P-V curve of the PV array has been simulated for pattern II and shown in fig.10. In this case, two local MPPs evolve first followed by a global MPP. Global search accurately identified the GMPP and the PV system has settled at this power level.

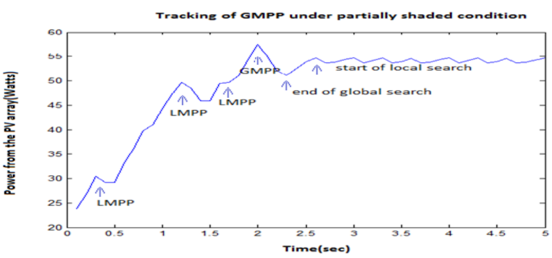

Fig. 11. Tracking of GMPP for pattern III

P-V curve of the PV array has been simulated for pattern III and shown in fig.11.In this case, three local MPPs evolve first followed by a global MPP. In this kind of P-V curve of the PV array GMPP has been identified exactly by global search and the PV system settled at this power level through local search.

VII. Conclusion

The simulation results show that the proposed global MPPT techniques successfully tracks the global maximum power point within reasonable time as the step size for duty cycle is large during the global search. Then local search makes the operating point to reach the global maximum power point with minimum oscillations as the step size is very small. Therefore magnitude of oscillations as well as search time around global MPP are abridged considerably thus improving the overall system efficiency and tracking efficiency. Simulation was done by using MATLAB/SIMULINK environment coupled to PSIM software for dissimilar partial shading conditions and the results show that the proposed MPPT is capable of reaching the global MPP under any partial shading conditions. Under partial shading conditions and rapidly varying irradiance conditions conventional MPPT methods fail to track real maximum power point. To overcome this situation, an improvement in conventional MPP tracking algorithm is done and integrated with modified SEPIC converter. The above mentioned MPPT system is able to track the real maximum power point under constant and varying weather conditions.

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