International Journal of Research in Advent Technology, Vol.3, No.9, September 2015
E-ISSN: 2321-9637
Available online at www.ijrat.org

Energy Recovery from Partially Shaded Photovoltaic Modules using PSO Based MPPT

Aswathy V V [1], Reshmi V [2]
EEE Dept, Amal Jyothi college of enginnering , Kanjirapally,
Student [1] , Assistsnt Professor [2]
Email: achuzz18@gmail.com [1], *vreshmi@amaljyothi.ac.in* [2]

Abstract- A simple circuit with PSO based MPPT, to recover the energy that will be lost due to the partial shadings on PV modules is proposed in this thesis. The circuit can be readily retrofitted to an existing PV system. The main idea of the scheme is that, during partial shading, parts of the current from the non-shaded modules are harvested by an energy recovery circuit using power electronic switches and storage components. This paper evaluates and compares the proposed method with the conventional P&O algorithm based MPPT. To investigate the idea, an experimental analysis will be done to find the effects of shading and simulation study o the proposed system will be done using MATLAB/SIMULINK model.

Keywords – Solar PV; Partial shading; Energy recovery; MPPT; Boost converter.

1. INTRODUCTION

Energy is the prime mover of economic growth and the vital element for sustaining a modern economy and society. Future economic growth significantly depends on the long term availability of energy from sources that are affordable, accessible and secure. As a result of world energy crisis and the growing demand for energy, conventional energy sources becomes unable to cope with the world energy demand. According to a 2011 projection by the International Energy Agency, solar power generators may produce most of the world's electricity within next 50 years, dramatically reducing the emissions of greenhouse gases that harm the environment.

Photovoltaic energy is a source of interesting energy; it is renewable, inexhaustible and nonpolluting. It is more and more intensively used as energy sources in various applications as it is considered to be one of the most efficient and well-accepted renewable energy sources because of their suitability in distributed generation, mobile applications, transportation, and satellite systems In regard to endless importance of solar energy, it is worth saying that solar energy is a unique perspective solution for energy crisis [1]. Unfortunately, PV generation systems have two major problems: the conversion efficiency of electric power generation is low and the amount of electric power generated by solar arrays changes continuously with weather conditions. Moreover, PV systems suffer from a major drawback which is the nonlinearity between the output voltage and current particularly under partially shaded conditions.

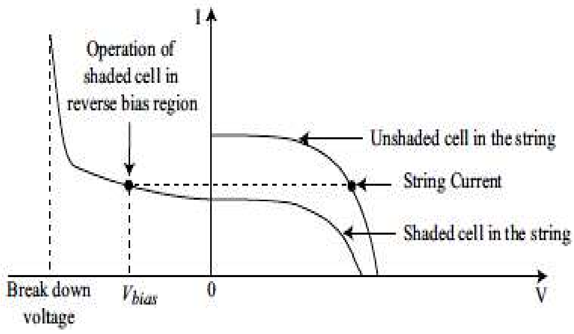

Fig.1: Effect of shading on solar PV cells

Partial shading of a solar PV module is one of the main causes of overheating of shaded cells and reduced energy yield of the module [2] [3]. A shadow falling on a group of cells will reduce the total output by two mechanisms: by reducing the energy input to the cell and by increasing energy losses in the shaded cells. Problems become more serious when shaded cells get reverse biased. This is because the shaded module acts as a load instead of a generator; consequently, a hot spot is created and if left unprotected, the module may experience irreparable damage. Typically, every module is connected to a bypass diode to divert the current in the case of partial shading occurrence. It must be noted that as long as the shaded module is being short-circuited by the bypass diode, it is totally unusable [4].

The paper proposes a simple circuit to recover the energy that otherwise would be lost due to the partial shadings on photovoltaic modules. Since the circuit can be readily retrofitted to an existing PV system, no modification is required. Several MPPT methods have been developed in relation to PV systems in order to reach the MPP. In this survey, the Perturb and Observe (P&O) and Practical Swarm Optimization (PSO) MPPT algorithms are presented and compared under partial shading conditions. A MATLAB simulation model that represents 36 cells PV module has been used to test several shading profiles and results are presented.

2. PROPOSED CIRCUIT

In this paper, a simple circuit that could be used for partial shading is proposed. The main feature of this approach is the ability to recover the power generated by the shaded module and then processes it to become part of the output power, enabling it deliver more power compared to the bypass diode topology.

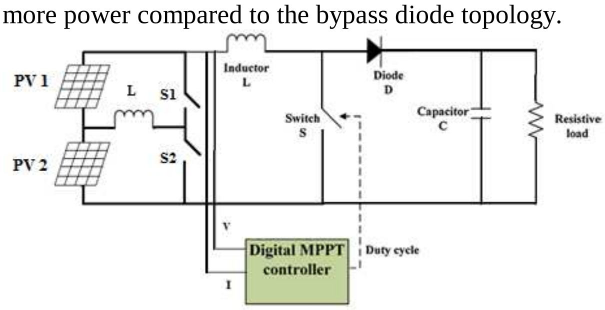

Fig.2: General Block Diagram of proposed circuit

Fig. 2 shows the overall circuit diagram of the proposed circuit to harvest the power from the shaded module. To illustrate the recovery concept, a string of two PV modules is used. The circuit is connected in parallel to the original PV modules, therefore, it can be easily retrofitted to the existing system with minimum changes in the electrical wirings. The basic idea of this topology is to transfer the power from non-shaded modules to the shaded modules until all modules in the string seem to have equal power level.

1.1 Energy recovery circuit

The main idea behind the proposed method is that, during partial shading (Assuming that PV1 is shaded and PV2 receives a full irradiation) part of the current from PV2 is diverted to the energy recovery circuit (by turning S2 ON and the energy is stored temporarily in a storage element, L. By doing so, the string current can be maintained at the level generated by PV1 and hence there is no need for PV1 to be bypassed. As a result, PV1 is still able to actively produce power (albeit in a lesser amount, depending on the shading condition) because its voltage is not zero. Meanwhile, the energy stored in L will be released back to the output via D1 (by turning OFF S2). Thus, ideally, using this scheme, no PV power is wasted except for the losses due to the switches, diodes, and the non idealities of the passive components. A particular dead time of is applied during transition of the paired switches. However, the dead time does not affect the overall behavior of the system.

Similarly, when PV2 is shaded and PV1 not shaded, under mode 1, *S*1 is turned ON. The current flows through *S*2, causing i_{L1} to increase linearly due to the constant voltage supply from PV1. Hence, part of the energy from the PV1 is temporarily stored in *L*1.during mode 2 operation, *S*2 is turned ON and *S*1 is turned OFF. When *S*1 is turned OFF, the current is forced to flow through the freewheeling diode, *D*2. The stored energy in *L*1 is released in the form of current and flows to the load.

The proposed circuit acts as a "balancing" element to equalize the currents between the shaded and non shaded modules. This implies that during the occurrence of partial shading, the energy from the shaded module is recovered and transferred to the load. Since the output current is increased, while the voltage across the shaded voltage is near its V_{MP}, the overall energy yield is increased. The maximum power point trackers are used to maintain the maximum power point. The MPPT minimize the overall system cost and maximize the array efficiency [5] [6]. Many algorithms have been proposed, in this paper an energy recovery circuit with Particle Swarm Optimization based MPPT Controller is used to find out the maximum power point.

1.2 PSO-based MPPT for PV Systems

PSO was introduced by James Kennedy and Russell C Eberhart in the year 1995. PSO is a stochastic, population-based EA search method, modeled after the behavior of bird flocks. The PSO algorithm maintains a swarm of individuals (called particles), where each particle represents a candidate solution [7]. Particles follow a simple behavior: emulate the success of neighboring particles and its own achieved successes. The position of a particle is, therefore, influenced by the best particle in a neighborhood *P* best as well as the best solution found by all the particles in the entire population G_{best}. The particle position x_i is adjusted using,

$$x_i^{k+1} = x_i^{k} + \Phi_i^{k+1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where, the velocity component Φi represents the step size. The velocity is calculated by,

$$\Phi_i^{k+1} = w\Phi_i^{k} + c_1 r_1 (P_{best} - x_i^{k}) + c_2 r_2 (G_{best} - x_i^{k}) ..(2)$$

where, w is the inertia weight, $c1$ and $c2$ are the acceleration coefficients, $r1$, $r2$, ε ,$U(0,1)$, $P_{\text{best},}i$ is the personal best position of particle i, and G best is the best position of the particles in the entire population.

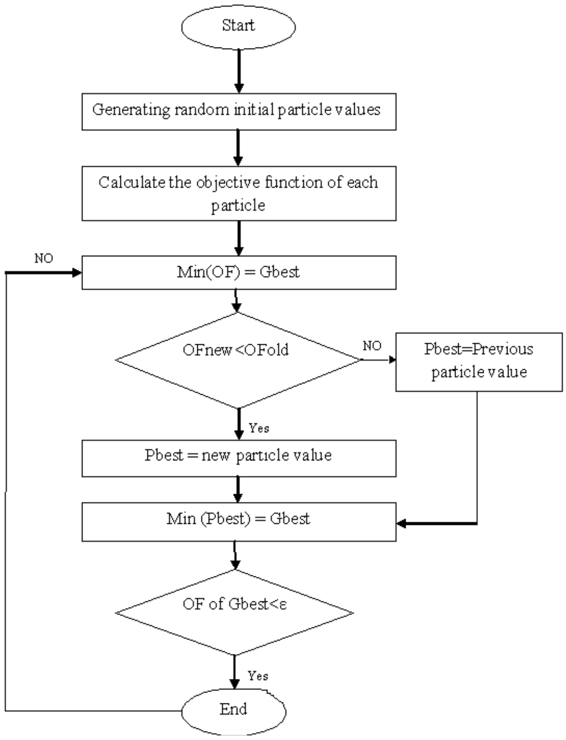

Fig. 3: Flowchart for PSO method

If position is defined as the actual duty cycle while velocity shows the perturbation in the present duty cycle, then equation can be rewritten as,

$$d_i^{k+1} = d_i^{k} + \Phi_i^{k+1} \quad \text{……………………….(3)}$$

However, for the case of PSO, resulting perturbation in the present duty cycle depends on P_{best} and G_{best}. If the present duty cycle is far from these two duty cycles, the resulting change in the duty cycle will also be large, and vice versa. In the latter, the perturbation in the duty cycle is always fixed but in PSO it varies according to the position of the particles. With proper choice of control parameters, a suitable MPPT controller using PSO can be easily designed.

Operating Principle of PSO based MPPT:

The figure 3 illustrates the flowchart of the PSO method [8],

i) Equation (1) shows that the perturbation in duty cycle is computed by two differerent terms: the difference between the previous duty cycle $d_i(k)$ and the local best particles, $P_{best,I}$, and the difference between the previous duty cycle $d_i(k)$ and the global best particle Gbest. Thus, the power converter tracks the two best $P_{best,i}$ and G_{best} at the same time. As a result, the tracking spaces are searched to obtain an optimal solution with a faster speed.

ii) Once the particle reaches MPP, the velocity of particles is practically zero. Hence, at steady state no oscillations will be seen. These steady-state oscillation are very critical because it is one of the major reasons for the reduced MPPT efficiency.

iii) In the case of rapid fluctuations in the environmental conditions, the P&O method can lose the direction of new MPP and tracking could be driven into a wrong direction. However, the proposed method works on three duty cycles. Since the operating power information is obtained from all three duty cycles, it never loses the direction of MPP in rapid fluctuations.

iv) In the condition of partial shading, the PV characteristic curve is characterized by multiple peaks. As a result, the conventional methods are most likely to trap at local maxima. On the other hand, the PSO method works based on a searching scheme. Hence, it can still track the global peak correctly [9]. A DC/DC boost converter serves the purpose of transferring maximum power from the solar PV cell to the load. It acts as an interface between the load and the PV cell. By varying the duty cycle of converter, the ratio of input and output voltage could be adjusted appropriately.

3. EXPERIMENTAL ANALYSIS

The proposed energy recovery system is validated using MATLAB-Simulink simulation and an experimental analysis on effects of shading was also conducted. Experimentally, the ELDORA 40PV module is used. Its peak rated power is 40 W (17.4 V / 2.30 A) at standard test conditions (STC). PV module under normal radiation The obtained results of the experiments are shown in Table. 1 and with the values obtained during normal radiation (no shading) and under partial shading were plotted in the following figures.

Table 1: PV module characteristics with and without shading

Sl No	No Shading			Shading		
	V (V)	I (A)	P (W)	V (V)	I (A)	P (W)
1	0	2.22	0	0	0.32	0
2	6.5	2.2	14.3	3.5	0.31	1.09
3	14.3	2.16	30.89	4.3	0.31	1.33
4	15.8	1.97	31.13	5.1	0.31	1.58
5	16.8	1.76	29.57	7	0.31	2.17
6	17.8	1.34	23.85	8.4	0.31	2.60
7	18.1	1.17	21.18	10.5	0.31	3.26
8	18.6	0.86	15.99	13	0.3	3.9
9	19	0.58	11.02	14.5	0.29	4.21
10	19.3	0	0	15.6	0	0

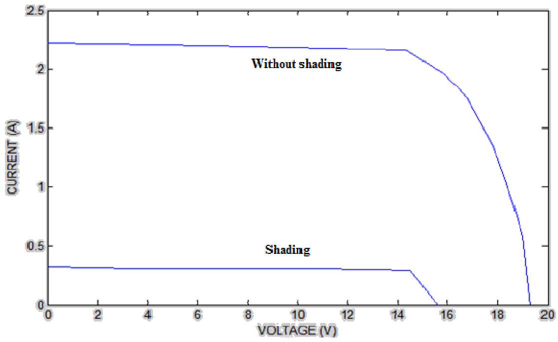

Fig 4: I-V characteristics of solar cell with and without shading

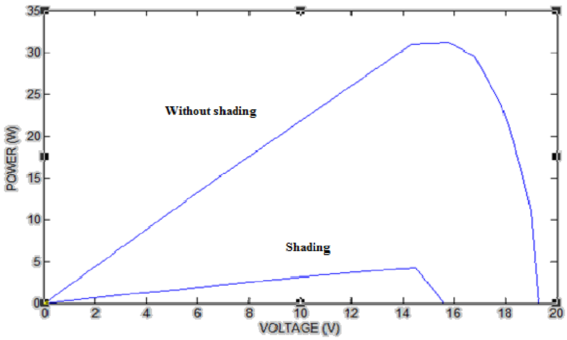

Fig 5: P-V characteristics of solar cell with and without shading

From the I-V characteristics and the P-V characteristics shown in Fig. 4 and Fig. 15 respectively, the variation of current and power with respect to voltage during normal radiation and partial shading conditions can be observed. Partial shading limits the output current and power. It can be concluded that, there is a substantial power loss due to non uniform illumination. The power generated by highly illuminated cells is wasted as a heat in the poorly illuminated cell resulting in destruction of the shaded module.

4. DESIGN AND SIMULATION

PV module represents the fundamental power conversion unit of a PV generator system. The output characteristics of a PV module depend on the solar insolation, the cell temperature and the output voltage of the PV module. Since PV module has nonlinear characteristics, an energy recovery circuit is necessary to model for designing and simulation of maximum power point tracking with boost converter for PV system applications [10].

Table 2: Electrical characteristics of 40W PV module

Rated power	P_m	**W**	**40**
Open circuit voltage	V_{oc}	V	21.90
Short circuit current	I_{sc}	A	2.45
Voltage at max power	V_{mp}	V	17.4
Current at max power	I_{mp}	A	2.30
Total no: of cells in series	N_s		36
Total no: of cells in parallel	N_p		1

Boost converter is designed using,

$$L > (V_oD(1-D)^2 T) / 2I_o$$

$$C < DT / (\Delta V/V_o)R$$

Energy recovery circuit is designed using,

$$L = V_{PV}DT / \Delta I_L$$

4.1 Simulation results

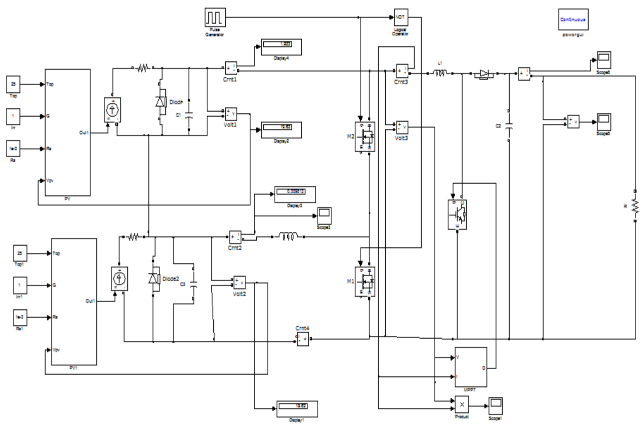

Fig 6: MATLAB simulink model of solar panel with energy recovery circuit and MPPT

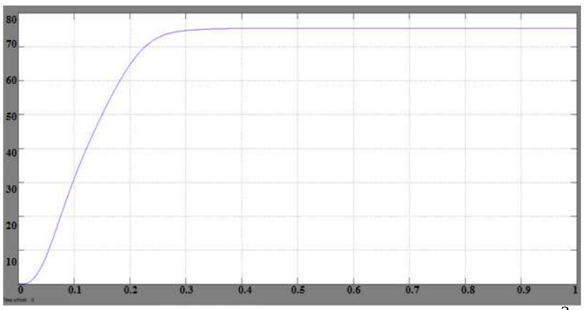

Fig 7:Power output when PV1 & PV2 = 1000 W/m^2

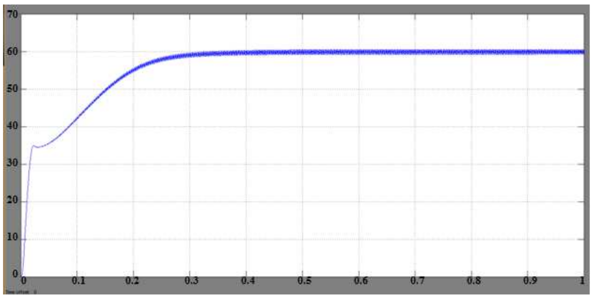

Fig. 8: Power output using energy recovery circuit when PV1 = 500 W/m^2 & PV2 = 1000 W/m^2

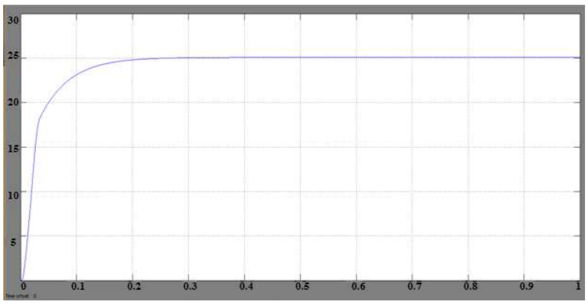

Fig. 9: Power output without using energy recovery circuit when PV1 = 500 W/m^2 & PV2 = 1000 W/m^2

Under normal radiation, output power obtained is almost 75 W. Under partial shading (=500 W/m^2), the output power is only 25 W without using an energy recovery circuit is about 60 W using energy recovery circui. Hence, it can be concluded that, with an energy recovery circuit, the power that is lost during partial shading can be recovered and thus no module remains unusable.

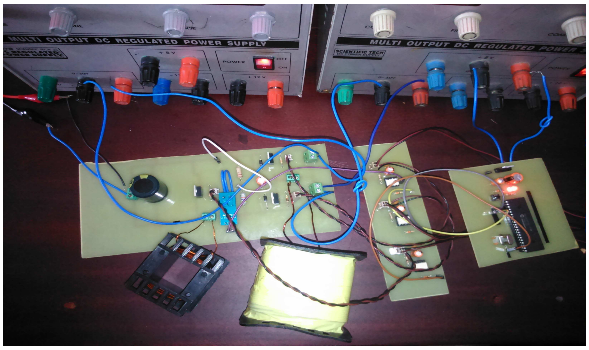

Figure 10: Hardware setup

5. CONCLUSION

A simple circuit is proposed to increase the output power of PV system during partial shading.. Consequently, the inclusion of the proposed circuit with PSO based MPPT enables the system to deliver more power compared to traditional methods. The results indicate that the proposed PSO controller outperforms and gives a number of advantages. It could locate the MPP for any environmental variations including partial shading condition and large fluctuations of insolation. Experimental study done on a 40W PV module shows variation in output power during normal radiation and partial shading. Simulation study using MATLAB/SIMULINK model with energy recovery circuit results in marked improvement in the output power, especially under heavy partial shading conditions. The extra power generated is expected to compensate for the cost of the extra components in the retrofit circuit and generates profit in the long run.

REFERENCES

[1] Dezso Sera, Yahia Baghzouz “On the Impact of Partial Shading on PV Output Power”, Proceedings of RES'08,WSEAS Press, 2008

[2] Ali Bidram, Ali Davoudi and Robert S. Balog,” Control and Circuit Techniques to Mitigate Partial Shading Effects in Photovoltaic Arrays”, IEEE Journal Of Photovoltaics, Vol. 2, No. 4, October 2012

[3] Hla Hla Khaing, Yit Jian Liang, Nant Nyein Moe Htay, Jiang Fan,"Characteristics of Different Solar PV Modules under Partial Shading", International Journal of Electrical, Computer, Electronics and Communication Engineering, Vol:8, No:9, 2014

[4] Huiying Zheng, Shuhui Li,"Design of Bypass Diodes in Improving Energy Extraction of Solar PV Systems under Uneven Shading Conditions", IEEE, 2014

[5] S.Gomathy, S.Saravanan, Dr. S. Thangavel , “Design and Implementation of Maximum Power Point Tracking (MPPT) Algorithm for a Standalone PV System ”, International Journal of Scientific & Engineering Research Volume 3, Issue 3, March -2012

[6] Z. SalamM. Z. Ramli, “A Simple Circuit to Improve the Power Yield of PV Array During Partial Shading”, IEEE conference, 2012

[7] Bader N. Alajmi, Khaled H. Ahmed, Stephen J. Finney, and Barry W. Williams,” A Maximum Power Point Tracking Technique for Partially Shaded Photovoltaic Systems in Microgrids”, IEEE transactions on industrial electronics, vol. 60, no. 4, April 2013

[8] Selvapriyanka. P, Vijayakumar. G, "Particle Swarm Optimization Based MPPT for PV System under Partial Shading Conditions",International Conference on Engineering Technology and Science-(ICETS14), Volume 3, Special Issue 1, January 2014

[9] Kashif Ishaque, Zainal Salam, Muhammad Amjad, and Saad Mekhilef, "An Improved Particle Swarm Optimization (PSO)Based MPPT

for PV With Reduced Steady-State Oscillation",IEEE Transactions on Power Electronics, Vol. 27, No. 8, August 2012

[10] N. Pandiarajan and Ranganath Muthu," Mathematical Modeling of Photovoltaic Module with Simulink", International Conference on Electrical Energy Systems (ICEES 2011), 3-5 Jan 2011