MAXIMUM POWER POINT TRACKING METHOD BASED ON MODIFIED PERTURB AND OBSERVE COMBINED WITH PARTICLE SWARM OPTIMIZATION

[1] *DR. E LATHA MERCY,* [2] *ANU CHACKO*

[1] **Associate Professor/Dept. of EEE, GCT, Coimbatore-13,**
[2] **PG Scholar/Dept. of EEE, GCT, Coimbatore-13**

mercy@gct.ac.in,anuchacko107@gmail.com

ABSTRACT- *This paper presents a new hybrid Maximum Power Point Tracking(MPPT) method based on Modified Perturb and Observe(P & O) combined with Particle Swarm Optimization(PSO). Initially, the Modified P & O method is employed to track the Local Maximum Point and from that point PSO is employed to track the Global Maximum Point. Modified P & O is used to avoid the poor tracking at rapidly changing weather conditions. The advantage of using this proposed method is the search space required for PSO is reduced and the time required for convergence will be greatly improved. Results show the effectiveness of using the new hybrid method for maximum power point tracking.*

Keywords- Maximum Power Point Tracking (MPPT), Perturb and Observe (P & O), Local Maximum Point (LMP), Global Maximum Point (GMP), Particle Swarm Optimization (PSO).

1. INTRODUCTION

Recent advances in power electronics have developed many algorithms for tracking maximum power point. Among these, perturb-and-observe (P&O), hill-climbing (HC), and incremental conductance (INC) are the most commonly used methods [1]–[3]. As shown in [4] and [5], these methods rely on same method of determining the gradient of the power with respect to the current or voltage using the perturbation method in each iteration. The disadvantage of these methods is that when the first local maximum point (LMP) is reached, the algorithms stop progressing to the next maximum point (if there is any) that is, it converges only to single LMP, which is only appropriate under uniform insolation conditions.

Under partially shaded conditions, shaded cells in the module becomes reverse biased and will not conduct and act as a load leading to hot spot problem. In order to avoid this problem bypass diodes are connected across partially shaded cells to conduct the current from non shaded cells. However, the connection of bypass diodes will change the uniform current–voltage (*I–V*) and power–voltage (*P–V*) characteristics of the module, which results in multiple peaks [6]. In order maximize the efficiency of the module, it is necessary to track the global maximum point (GMP). Two approaches are generally used to reduce or counteract the shading effect. The first one is based on hardware fixtures, such as adaptive reconfiguration schemes for the PV arrays [7] and multilevel converter systems [8] which allow each PV source to be controlled separately. This approach is complex and costly [9]. The second approach is to track the GMP by developing advanced control algorithms, and this will be the focus of this paper.

This paper proposes a hybrid method employing both Modified P & O and PSO in order to track the GMP. Initially, Modified P & O is applied to locate the LMP and from that point onwards PSO is applied to find the GMP from the entire search space. Modified P & O is used to avoid the poor tracking at rapidly changing weather conditions. The advantage of using this proposed method is the search space required for PSO is reduced and the time required for convergence will be greatly improved.

2. BLOCK DIAGRAM

The block diagram of the proposed system is shown in figure 1. The generated voltage (V_{PV}) and current (I_{PV}) from PV array is given to the boost converter. The switching operation of the switch is controlled with the help of duty cycle obtained from MPPT algorithm. The MPPT algorithm used is a hybrid algorithm which is a combination of Modified P & O with PSO. The converter used is a boost converter. The output of the converter is given to a resistive load and the output gets boosted up.

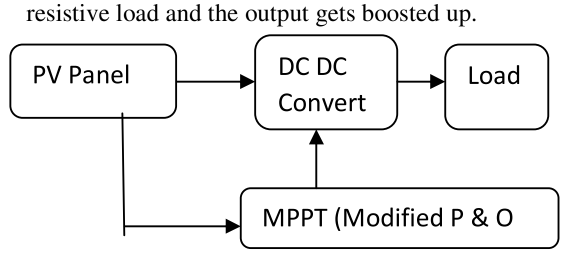

Fig 1: Block diagram of proposed system

3. BOOST CONVERTER

A boost converter is a Dc Dc converter with an output voltage greater than the input voltage. It consists of atleast two semiconductor switches (a diode and a transistor) and atleast one energy storage element that is a capacitor or an inductor or a combination of both. The principle that drives the boost converter is the tendency of an inductor to resist changes in current by creating and destroying the magnetic field. When the switch is closed, current flows through the inductor in clockwise direction and the inductor stores some energy by generating a magnetic field. Polarity of the left side of the inductor is positive. When the switch is opened, current will be reduced as the impedance is higher. The magnetic field previously created will be destroyed to maintain the current flow towards the load. Thus the polarity will be reversed (means left side of inductor will be negative now). As a result two sources will be in series causing a higher voltage to charge the capacitor through the diode D. The basic principle of a Boost converter consists of 2 distinct states:

- In the On-state, the switch S is closed, resulting in an increase in the inductor current
- In the Off-state, the switch is open and the only path offered to inductor current is through the flyback diode D, the capacitor C and the load R. These results in transferring the energy accumulated during the On-state into the capacitor.

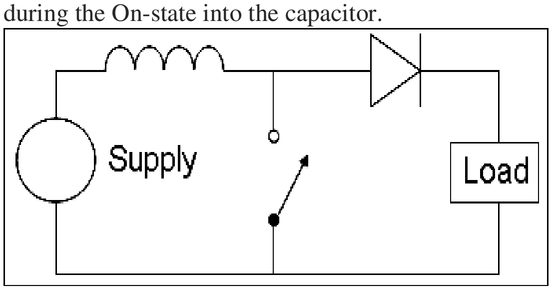

Fig.2 Boost Converter

The converter used is a boost converter and the supply to the inverter is given using a solar panel. The equivalent circuit of a PV cell is shown in figure.3

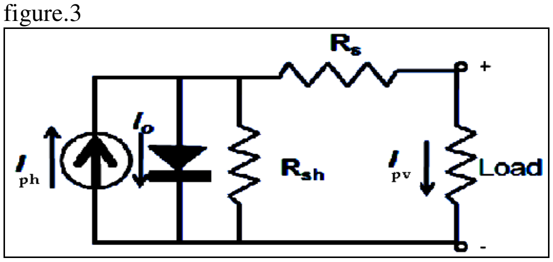

Fig.3 Equivalent circuit of PV panel

The modelling of PV panel is carried out using the following basic equations.

$I = N_p I_{ph} - I_d - I_{sh}$

Photo current equation is computed by, the light generated current of the PV cell I_{ph} depends linearly on the solar irradiance and temperature according to the following equation,

$$I_{ph} = \frac{Si}{1000}\{I_{sc} + K_i(T - T_r)\}$$

By the Schottky diode equation, the current divided through the diode (neglecting series resistance R_s) is,

$$I_d = N_p I_0 \{e^{\frac{q(V_{pv} + I_{pv} R_s)}{N_s AKT}} - 1\}$$

The reverse saturation current is given as,

$$I_0 = I_{rs}\left(\frac{T}{T_r}\right)^3 e^{\frac{qE_g}{3K}\left(\frac{1}{T_r} - \frac{1}{T}\right)}$$

By Ohm's law, the current diverted through the shunt resistor is,

$$I_{sh} = \frac{V0}{N_s R_{sh}}$$

Substituting these into the first equation produces the characteristics equation of a solar cell, which will relates solar cell parameters to the output current and voltage,

$$I_{rs} = \frac{I_{scr}}{e^{\frac{qV_{oc}}{N_s KAT}} - 1}$$

From the above equations,

I_{sc} is cell's short circuit current(A),K is the temperature coefficient(0.0017A/K),T_c is the operating temperature(°C), T_{ref} is the reference temperature(°C), H is solar insolation (kW/m^2), q is charge of electron (1.6×10^{-19}C), V_{oc} is open circuit voltage(V), N_s is number of cells connected in series(36), k is Boltzmann constant(1.38×10^{-23} J/K), A is ideal factor(1.6), Ego is band gap energy(1.1eV), N_p is number of parallel connection of cell(1).

4. MODIFIED PERTURB & OBSERVE METHOD

The Modified P & O method is an improved P&O algorithm in order to avoid the poor tracking at rapidly changing weather by adding a new variable, irradiation (S), to the measured components. An irradiance sensor is connected to the MPPT control unit in order to detect the irradiance amount regularly and compare it with the previous value. At certain point, when the different between S(k) and S(k+1) is higher than a fixed value 'M' then the algorithm will recognise that there is an irradiance change and the algorithm should start the process from the beginning. The value of M is set depend on the PV criteria and it is different for each PV. Fig.4 shows the flowchart for the new approach, which looks similar to the conventional P&O method but with the irradiance sensing calculation. The control unit is programmed so the MPPT realize whether the output power has increase due to the change in the duty-cycle or a weather changing has occurred. If the reason was a weather changing and the new value was positive and higher, the MPPT will decrease the terminal voltage, while in the conventional P&O the MPPT will keep increasing the operation voltage value.

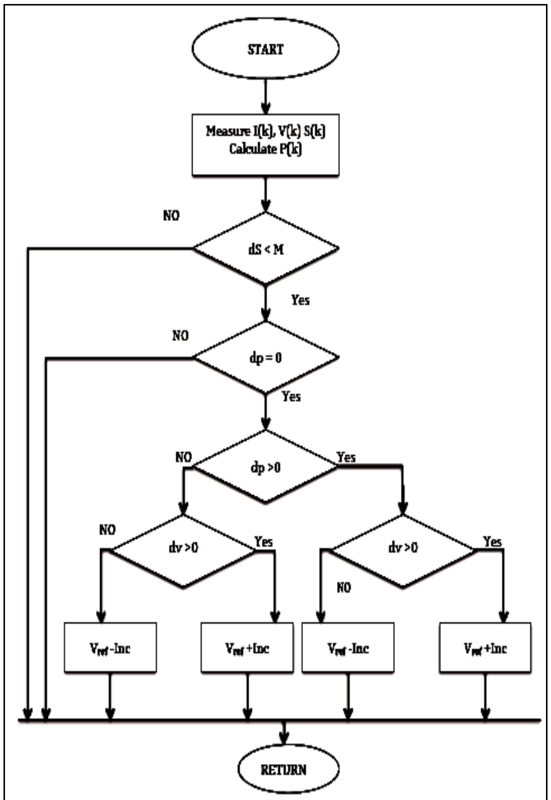

Fig.4 Flowchart of Modified P & O

5. PARTICLE SWARM OPTIMIZATION ALGORITHM

The PSO method is a metaheuristic approach that can be applied to optimize a function which is difficult or impossible to express analytically. The main objective of using the PSO method is to find the best optimum solution for a given problem. In the proposed system, it is used to find the maximum power point that is GMP at partially shaded conditions. The flowchart of PSO is shown in figure 5. The PSO algorithm can be expressed mathematically by two equations which specify the velocity and position update of a particle *i*.

$$u_i^{k+1}=wu_i^k+c_1r_1(P_{besti}-x_i^k)+c_2r_2(G_{besti}-x_i^k) \qquad (1)$$

$$x_i^{k+1}=x_i^k+u_i^{k+1} \qquad (2)$$

where u_{ki} is the velocity of individual i at iteration k, ω is an inertia weight parameter, $c1$ and $c2$ are acceleration coefficients, $r1$ and $r2$ are random numbers between 0 and 1, x_{ki} is the position of individual i at iteration k, *p*besti is the best position of individual i at iteration k, and *g*best is the best position of the group up to iteration k. The value of ω can be determined by an equation or set to a fixed value. The purpose of the MPPT block is to obtain *V*ref, which is sent to the PI controller. Therefore, the position (x) variables in (1) and (2) are actually the voltage references (*V*ref), whereas the velocity (u) variables can be regarded as the correction terms for the voltage references. Since the converter can only respond to one command at a time, the particles are initialized and evaluated in a successive manner. The interval between successive particles, *T*int, must be greater than the settling time of the system in order to obtain correct current and voltage samples. Fig. 5 summarizes the control action of the PSO method used for MPPT. In the first iteration, *V*ref is initially set to some value. It is then updated according to (1) and (2). The power *P*pv,*i* is calculated by multiplying the measured voltage (*V*pv) and current (*I*pv). Then, the algorithm proceeds to check whether this voltage reference value will result in a better individual fitness value by evaluating the following equation:

$$P_{pv,i} > P_{pv,i}-1 \qquad (3)$$

If (3) is satisfied, the individual fitness value (*p*besti) is updated; otherwise, *p*besti retains its present value. *P*pv,*i* is then checked against the power of the other particles to see if the global fitness value (*g*best) requires updating. A sufficient amount of time must be provided for each particle to perform all the aforementioned steps. Finally, the convergence criterion as defined in (4) is checked to ensure that all the particles converge to the GMP

$$|P_{pv,g_{best}}-P_{pv,i}|<\mathcal{E}_1 \qquad ,i=1............n \qquad (4)$$

where $\mathcal{E}_1$ is the tolerance value.

The LMP obtained using Modified P & O is given as the initial value of the PSO. From that point, the iteration process of this method starts and get terminated when the equation (4) is satisfied. By increasing the value of the tolerance value used, the accuracy of the algorithm can be increased. The output of the algorithm is used to control the on and off time of the converter used.

6. SIMULATION RESULTS

In this paper, the converter used is a boost converter and the algorithms used are the Modified P & O and PSO. The input to the converter is given using a solar panel of 30 Watts. The Modified P & O is used to find the first LMP and PSO is used to find the GMP from the entire search space. The combination of these two algorithms can reduce the time and space required for the convergence to the GMP. Solar Panel of 30 W is modelled using the basis standard equations of the solar cell with the help of the parameters mentioned on the data sheet of the corresponding PV panel. Initially, Modified P & O is modelled in MATLAB/Simulink to get the LMP. After this, PSO is applied to get the GMP from the entire search plane by setting the LMP obtained using Modified P & O as the initial value of this algorithm. Duty cycle is the output result of the MPPT method used. By, increasing the tolerance value used in the iteration, the accuracy of the output can be increased. The duty cycle is used to control the switches of the converter used such as Turn On and Turn Off times of the switch. By using the boost converter, the output is boosted up to a level of 65 V. The analysis shows that this algorithm reduces the convergence time used for obtaining GMP.

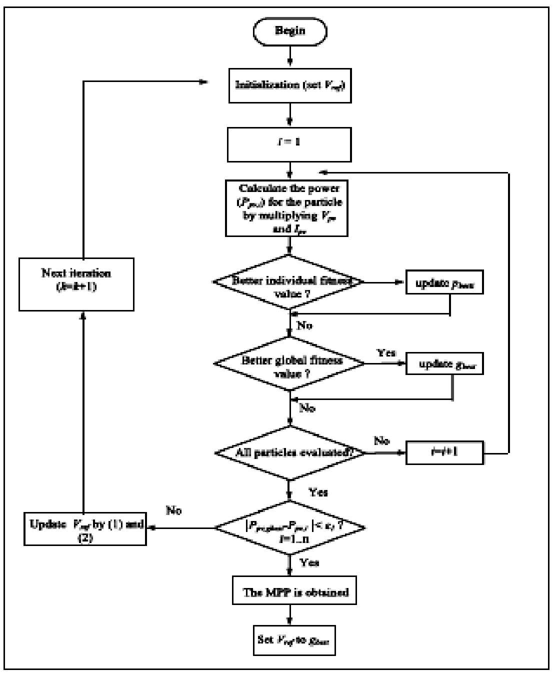

Fig.5 Flowchart of PSO Method

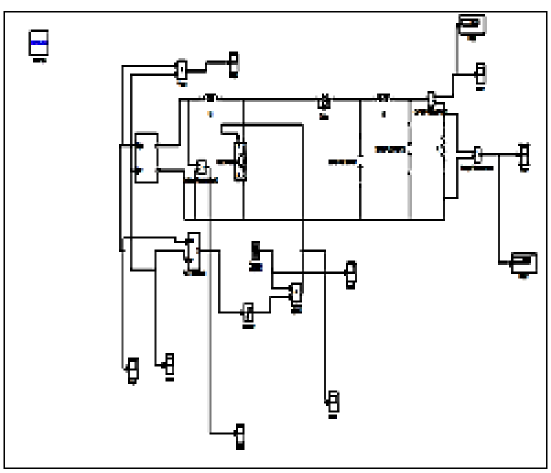

Fig.6 Simulink Model of Boost Converter

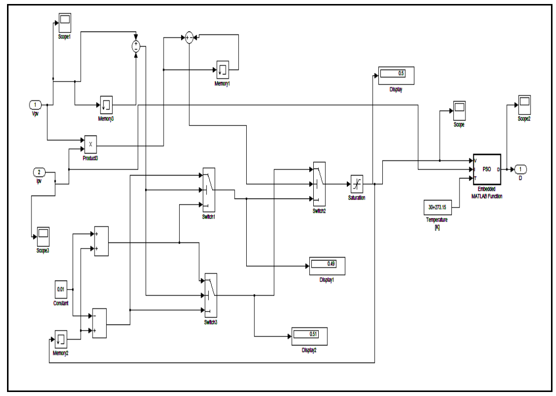

Fig.7 Simulink Model of MPPT algorithm

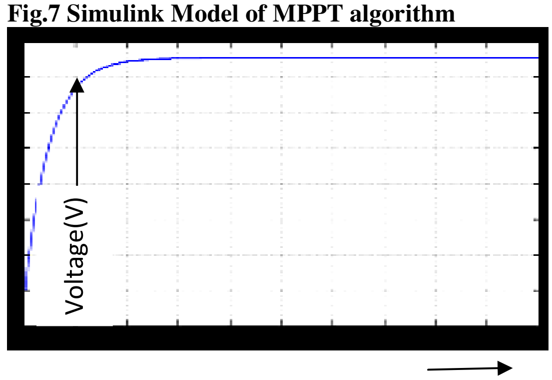

Fig.8 Output of Boost Converter

7. HARDWARE IMPLEMENTATION

MPPT algorithm which is simulated in the MATLAB/Simulink is implemented in hardware. The figure 9 shows the block diagram of the proposed hardware system.

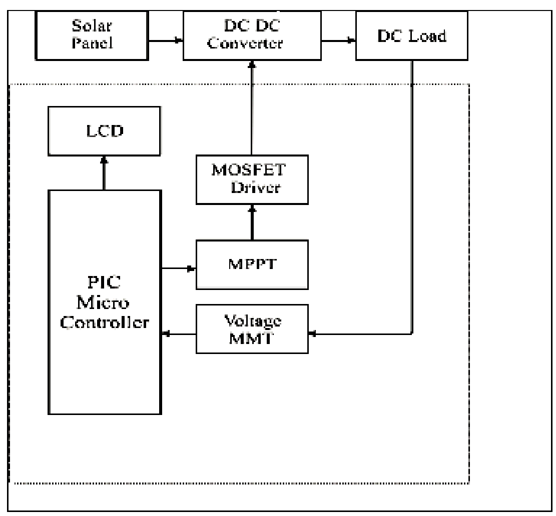

Fig.9 Block Diagram of Proposed Hardware System

Figure10 shows the hardware setup consisting of the step down transformer, rectifier circuit, PIC 16F877 and the boost converter circuit. The supply voltage of 240V is stepped down to 5V and 12V by the step down transformer and this voltage is given to controller and converter circuit respectively. The stepped down voltage will have so many ripples and because of this the output will not be a steady DC. In order to achieve a smooth steady DC filters and regulators are used . PIC is used to control the switch of the converter using the algorithm along with the driver circuit. Output voltage is taken across the load terminals of the converter. Output is boosted up to a voltage of 48.7V which is displayed in multimeter shown in the figure 11.On comparing the results of both simulation and hardware, it is seen that the simulation results is higher than the real time results.

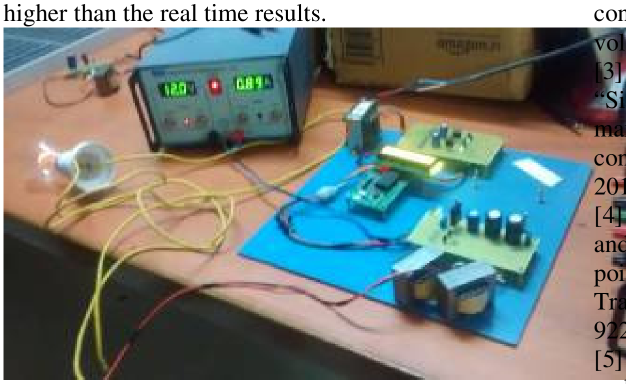

Fig.10 Hardware Setup

Fig.11 Hardware Result

Table I. Comparison of Simulation and Hardware Result

Output	Simulation	Hardware
Voltage	65V	48.7V

8. CONCLUSION

In this paper, a hybrid algorithm which is a combination of Modified P & O and PSO is proposed. The output of the algorithm is used to control the switch of the converter. The converter used here is a boost converter. The supply to the converter is given through a solar panel of 30W. Conventional MPPT methods such as P&O method can only track the first LMP and stop progressing to the next maximum point. MPPT methods based on PSO have been proposed to track the GMP. However, the problem with the PSO method is that the time required for convergence may be long if the range of the search space is large**.**

Modified P&O is used to track the first LMP and PSO is used to find the GMP from the entire search space. The simulation is done using MATLAB/Simulink and with the use of the boost converter, output is boosted up to a voltage level of 65 V and the performance of the algorithm used is verified by using an experimental setup.

REFERENCES

[1] Bidram, A. Davoudi, and R. Balog, “Control and circuit techniques to mitigate partial shading effects in photovoltaic arrays,” IEEE J. Photovoltaics, Oct. 2012 vol. 2, no. 4, , , pp. 532–546.

[2] A. Safari and S. Mekhilef, “Simulation and hardware implementation of incremental conductance MPPT with direct control method using Cuk converter,” IEEE Trans. Ind. Electron., Apr. 2011, vol. 58, no. 4, pp. 1154–1161.

[3] T.K. Soon, S. Mekhilef, and A. Safari, “Simple and low cost incremental conductance maximum power point tracking using buck-boost converter,” J. Renewable Sustainable Energy, 2013,vol. 5, no. 2, pp. 0 231 061–02 310 612.

[4] S. Kjaer, , “Evaluation of the hill climbing and the incremental conductance maximum power point trackers for photovoltaic power systems,” IEEE Trans. Energy Convers., Dec. 2012 vol. 27, no. 4, pp. 922–929.

[5] D. Sera, L. Mathe, T. Kerekes, S. Spataru, and R. Teodorescu, “On the perturb-and-observe and incremental conductance MPPT methods for PV systems,” , Jul. 2013 IEEE J. Photovoltaics, vol. 3, no. 3, pp. 1070–1078.

[6] Syafaruddin, E. Karatepe and T. Hiyama, , “Artificial neural network-polar coordinated fuzzy controller based maximum power point tracking control under partially shaded conditions,” IET Renewable Power Generation, Jun. 2009 vol. 3, no. 2, pp. 239–253.

[7] D. Nguyen and B. Lehman, , “An adaptive solar photovoltaic array using model-based reconfiguration algorithm,” IEEE Trans. Ind. Electron., Jul. 2008 vol. 55, no. 7, pp. 2644–2654.

[8] I. Abdalla, J. Corda, and L. Zhang, , “Multilevel dc-link inverter and control algorithm to overcome the PV partial shading,” Jan. 2013 IEEE Trans. Power Electron., vol. 28, no. 1, pp. 14–18.

[9] E. Koutroulis and F. Blaabjerg, “A new technique for tracking the global maximum power point of PV arrays operating under partial-shading conditions,” IEEE J. Photovoltaics, , Apr. 2012 vol. 2, no. 2, pp. 184–190.

[10] K.Kobayashi, I. Takano, andY. Sawada, “A study on a two stage maximum power point tracking control of a photovoltaic system under partially shaded insolation conditions,” , Jul. 2003 in Proc. IEEE Power Eng. Soc. General Meeting, vol. 4, pp. 2612–2617.

[11] B.Alajmi, K. Ahmed, S. Finney, and B. W. Williams, , “A maximum power point tracking technique for partially shaded photovoltaic systems in microgrids,” Apr. 2013, IEEE Trans. Ind. Electron., vol. 60, no. 4, pp. 1596–1606.

[12] M. Miyatake, T. Inada, I. Hiratsuka, H. Zhao, H. Otsuka, and M. Nakano, ,“Control

characteristics of a Fibonacci-search-based maximum power point tracker when a photovoltaic array is partially shaded," in Proc. Int. Power Electron. Motion Control Conf., Aug. 2004 vol. 2, pp. 816–821.

[13] P. Lei, Y. Li, and J. Seem, "Sequential ESC-based global MPPT control for photovoltaic array with variable shading," IEEE Trans. Sustainable Energy, , Jul. 2011, vol. 2, no. 3, pp. 348–358.

[14] L.-R. Chen, C.-H. Tsai, Y.-L. Lin, and Y.-S. Lai, "A biological swarm chasing algorithm for tracking the PV maximum power point," IEEE Trans. Energy Converters., Jun. 2010, vol. 25, no. 2, pp. 484–493.

[15] M. Miyatake, M. Veerachary, F. Toriumi, N. Fujii, and H. Ko, , "Maximum power point tracking of multiple photovoltaic arrays: A PSO approach", IEEE Trans. Aerospace Electron. Syst., Jan. 2011 vol. 47, no. 1, pp. 367–380.

[16] K. Ishaque , Z. Salam, M. Amjad , and S. Mekhilef, "An improved particle swarm optimization (PSO)—based MPPT for PV with reduced steady state oscillation" ,IEEE Trans. Power Electron., Aug. 2012 , vol. 27, no. 8, pp. 3627– 3638.

[17] Y.-H. Liu, S.-C. Huang, J.-W. Huang, and W.-C. Liang, "A particle swarm optimization-based maximum power point tracking algorithm for PV systems operating under partially shaded conditions,", IEEE Trans. Energy Converters., Dec. 2012 vol. 27, no. 4, pp. 1027–1035.