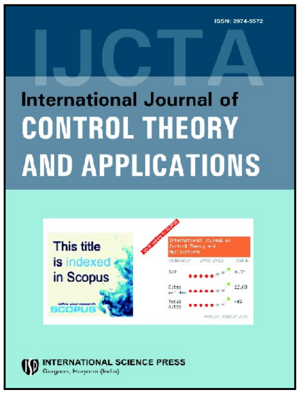

International Journal of Control Theory and Applications

ISSN : 0974-5572

Volume 10 • Number 6 • 2017

Hybridization of Perturb and Observe Method using PSO and ABC for Photovoltaic Grid Connected System

P. Sudheer and Ch. Chengaiah

Department of EEE, S.V.U.College of Engineering, S. V. University, Tirupati, Andhrapradesh, India
E-mail: psudheer35@gmail.com; chinthapudisvu@gmail.com

Abstract: Renewable energy sources plays a crucial role, in accomplishing the energy requirements of the current fastly growing world .Solar photovoltaic energy is the most notable energy resource, among different renewables to yield electricity. It follows the principle of photovoltaic effect. In the Photovoltaic system the variation in the maximum power point because of its non-linear characteristic of I-V and P-V with varying solar irradiance and temperature conditions. It is very complicate to track the maximum power point in real time. To overcome this complication many maximum power point tracking methods have been proposed and implemented. This paper projected a new hybrid perturb and observe method (HPO) and it is tested on grid connected photovoltaic system for different irradiations and temperatures. It is a combination of perturb and observe method and most popular optimization algorithms like particle swarm optimization (PSO) and Ant bee colony (ABC). This work implemented through the MATLAB/ SIMULINK Environment and the results showed that the proposed method is better compared to the conventional perturb and observe method.

Keywords: Maximum power, Tracking, Photovoltaic system, perturb and observe, particle swarm optimization, Ant bee colony

I. INTRODUCTION

To improve the efficiency and reduce the overall cost[1-3] of PV systems which is very need for now a days, the extraction of the maximum power from a solar cell is most important in the system design. At different appropriate operating points for a solar cell, there is a single operating point enables to get maximum power .The basic problem of MPPT is that, determining the PV output voltage or current for which the PV array produces maximum output power under a given irradiance and temperature automatically. Achievement of maximum power involves load-line adjustment under variations in irradiane and temperature. The maximum power point tracking, not only enables an increase in the power delivered from the PV module to the load, but also enhances the operating lifetime of the PV system [4]. A multiple of MPPT methods have been established and executed [5,6]. Consequently, an efficient maximum power point tracking technique is essential to track the maximum power point at all environmental conditions and then force the Photovoltaic system to operate at that maximum power point.

II. PHOTOVOLTAIC GRID CONNECTED SYSTEM

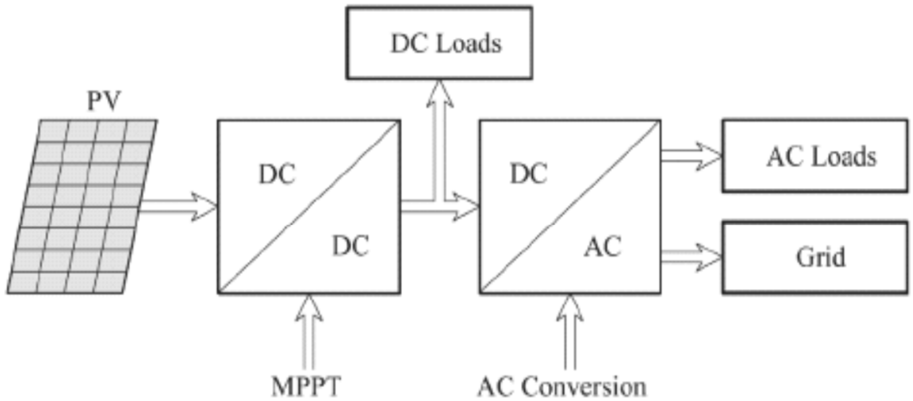

Figure 1: Schematic Diagram of Grid connected PV System

In the above Figure 1. a grid-connected PV System which is an electrical generation system is connected to the utility grid and AC loads. This grid-connected PV system includes the photovoltaic modules, number of inverters or a power conditioning unit, converters and grid connection etc. After converting DC power which comes from DC-DC Converter is utilized to convert into AC power by using inverters and it is finally fed to Grid or AC loads.

III. MODELLING OF PHOTOVOLTAIC MODULE

Photovoltaic module is the device which generates electrical energy by light energy form the sun. PV system Modelling requires[7], input variables as weather data (irradiance and temperature) and the output obtained as current, voltage, and power.

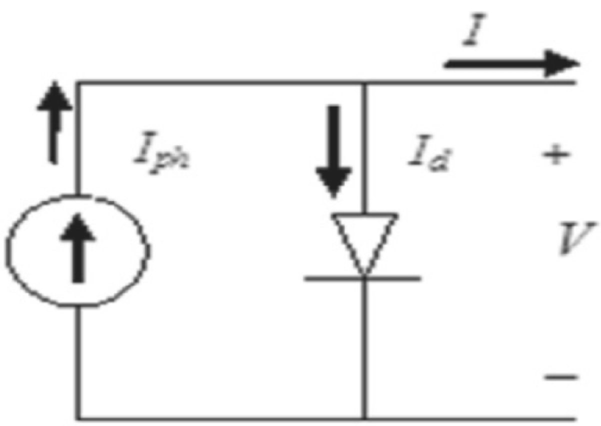

Figure 2: Ideal single diode model

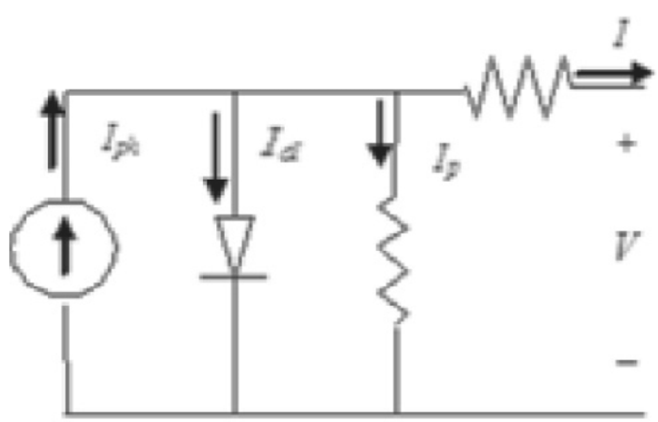

Figure 3: Practicalmodelwith Rs and Rp

The above parameters are very crucial, to plot the I-V and P-V characteristics. Any change in the input variables immediately changes the outputs. The ideal single diode model of PV cell shown in Figure 2 and the practical diode model with series and shunt resistance is shown in Figure 3. From these models the modelling equations were renowned for modelling which is revealed in the form of below equations.

From the model shown in Figure 2 the internal losses are does not considered. A diode is connected in anti-parallel with the light generated current source. The output current I is obtained by Kirchhoff law which is equation (1)

$$I = Iph - Id \tag{1}$$

I_{ph} is the photocurrent, I_d is the diode current which is proportional to the saturation current I_o

$$Id = Io(\exp\left(\frac{V}{A.Ns.Vt}\right) - 1) \tag{2}$$

V is the voltage imposed on the diode.

$$Vt = K.\ Tc/q \tag{3}$$

I_o is the reverse saturation or leakage current of the diode (A),

V_{tc} = 26 mV at 300 K for silisium cell,

Tc is the actual cell temperature (K), k Boltzmann constant,q is electron charge (1.602 · 10_19 C).

V_t is called the thermal voltage, Ns is the number of PV cells connected in series,A is the ideality factor.It is necessary to highlight that A is a constant which depends on PV cell technology. All the terms by which, V is divided in equation (2) under exponential function are inversely proportional to cell temperature and so, vary with varying conditions. In this paper, this term is designed by 'a' and called the thermal voltage (V).The thermal voltage 'a''is presented by equation (4). In Chouder *et al.* (2012)), 'a' is called ''the modified ideality factor'' and is considered as a parameter to determine.

$$a = \frac{Ns.A.K.Tc}{q} = Ns.A.\ Vt \tag{4}$$

By applying Kirchhoff law for the model of Figue.3, current will be obtained by the following equation:

$$I = Iph - Id - Ip \tag{5}$$

I_p, is the leakage current of parallel resistor. According to the equation (6), the output current of a module containing Ns cells in series and Np cells in parallel and it is represented by the below equation

$$I = Iph - Io(\exp\left(\frac{V + IRs}{a}\right) - 1) - \frac{V + IRs}{Rp} \tag{6}$$

The specific module parameters and it values are tabulated in Table.1.The I-V and P-V characteristics of the module and Array are shown in Figure.4 and Figure. 5. In this proposed simulated model, 96 cells are taken per module, 5 modules are connected in series to form as a string and totally 66 strings were connected in parallel to form an array. This Solar array is connected to the converter which is having the MPPT controller and it is fed to the grid after converted by the Inverter. The parameters of the module are tabulated in the table.1 and the I-V, P-V curve for the module and array are shown in the Figure 4, Figure 5 respectively. From these curves it is observed that the current, voltage and power generated from the module is 6A , 35V and 210W respectively. In the same way the array also generated current, voltage and power from the array is 400A, 200V and 80KW respectively.

Table 1
Parameters of SunPower SPR -305-WHT

Parameters	*Values*
Voc	64.2
Isc	5.96
Vmp	54.7
Imp	5.58
Rs	0.037998
Rp	993.51
Isat	1.175e-08
Iph	5.9602
Qd	1.3

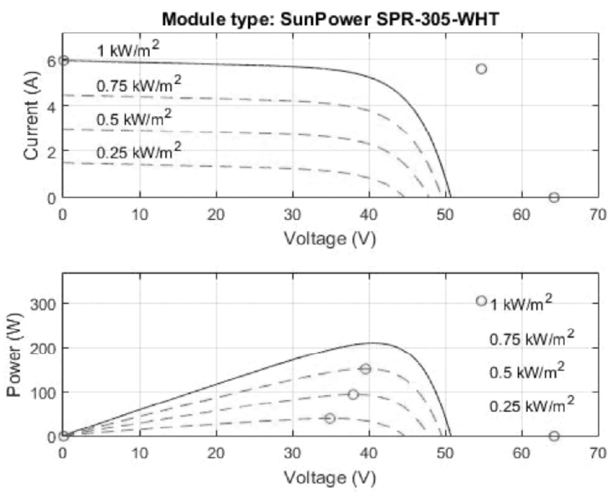

Figure 4: I-V,P-V characteristics of module

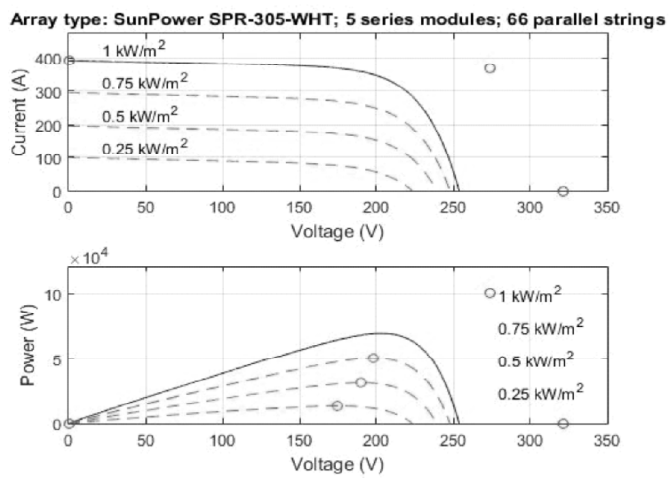

Figure 5: I-V,P-V characteristics of an array

IV. MAXIMUM POWER POINT TRACKING METHODS

Output characteristics of Photovoltaic system's is functions of irradiance , temperature and this output curves are nonlinear so it is very difficult to track the maximum power point. Moreover, the daily solar irradiation curves has changes abruptly during the day. Under these conditions, the MPP of the PV array also changes constantly, consequently the PV system's operating point must change to maximize the energy produced. Hence the MPPT technique is used to maintain the PV array's operating point at its MPP. MPPT methods available in the literature is enormous in number among those the most widely used conventional techniques are described in the following sections.

4.1. Perturb and observe method

The P&O algorithm is very simple to implement and also most frequently used in battery charging application with commercial PV modules[10] . In this method, the operating voltage or current of the PV module, is perturbed and then the power obtained is observed to decide the direction of further changes in the voltage or current. If the power is increased by the perturbation then voltage or current is keep on changing in the same direction until the power starts to fall. The algorithm measures the instant voltage (Vt) and current (It) to calculate the power (Pt) and then compare it with last calculated power (Pt-1). The algorithm continuously perturbs the system if the operating point variation is positive, otherwise the direction of perturbation is reversed if the operating point variation is negative. Because of this operating point variations oscillations are more recorded in this method. It is very obligatory to reduce this oscillations to get more accuracy operating point as maximum power point. The flow chart for perturb and observe is given in Figure.6.Huge works were carried out in this algorithms to reduce the oscillations as well as to increase the tracking performance, for this the modified perturb and observe method was developed which is explained in the following section.

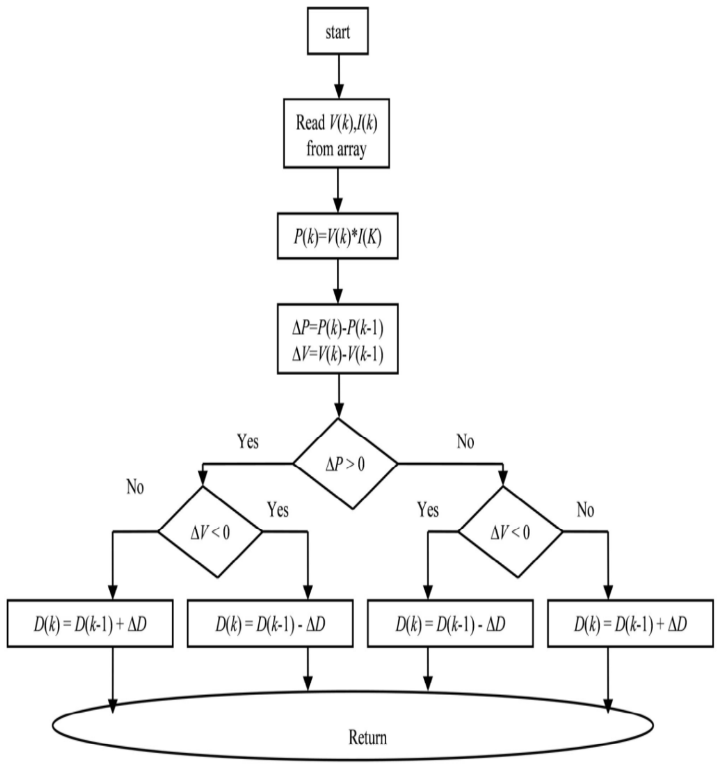

Figure 6: Perturb and observe method

4.2. Modified Perturb and observe method

The Modified perturb and observe method is better than the existed conventional method .In this method the step size is large up to steady state condition and it becomes small when it reaches the steady state condition. the The time taken to track maximum power point is decided by the step size (variable) and it is less in this algorithm.[10]

$$\text{Step size} = M\,(dp/dv)[11] \tag{7}$$

M is 0.002; dp is Change in Power; dv is Change in voltage.

4.3. Particle Swarm Optimization Method (PSO)

PSO is one of the population-based method, where the population is denoted as a *swarm*[8].It consists of a number of individuals called as *particles (duty cycles).*Each particle *i* in the swarm holds-(i) the current x*i*, which signifies a solution to the problem, (ii) the current velocity v*i*, (iii) the best position pbest*i*, the one associated with the best objective Function (i.e power) value the particle has achieved so far, and (iv) the neighborhood best position Gbest*i*, the one associated with the best objective function(power)value found in the particle's neighborhood. The choice of Gbest *i* depends on the neighborhood topology adopted by the swarm, In conventional PSO in every iteration, each particle moves to its own position towards its own best position. The following equations are followed in PSO method [8]

$$vt+1i\,j = w^*vti\,j + c1r1(pbesti\,j - xti, j) + c2r2(Gbesti \text{“} xti\,j) \quad (8)$$

$$xt+1i\,j = xti\,j + vt+1i\,j \quad (9)$$

$$pbest t+1 i = pbest i,\ \text{if } f(pbest ti) \le f(xt+1i), \quad (10)$$

$$= xt+1i,\ \text{if } f(pbest ti) > f(xt+1i).$$

$$Gbest = max(pbest) \quad (11)$$

for $j \in \{1...D\}$ where D is the number of dimensions, $i \in \{1...n\}$ where n is the number of particles,

t = number of iteration

w = inertia weights,

r1, r2 are random numbers between [0 1]

4.4. Artificial Bee Colony Method

Artificial Bee Colony (ABC) algorithm is very popular optimization algorithm among numerous algorithms.it is founded on the intelligent foraging behavior of honey bee swarm. [9]The colony of artificial bees consists of three groups of bees: employed bees, onlookers and scouts bees. An employed bee is useful to search the destination where food is available. They collect the food and return back to its origin, where they dance depending on the amount of food available at the destination. The onlooker bee watches the dance and follows the employed bee depending on the possibility of the available food. So, more onlooker bees will follow the employed bee associated with the destination having more amount of food. The employed bee whose food source becomes uncontrolled behaves as a scout bee and it searches for the new food source. This principle of foraging behavior of honey bee is used to solve optimization problems by dividing the population into two parts consisting of employed bees and onlooker bees. An employed bee searches the solution in the search space and the value of objective function associated with the solution is the amount of food associated with that solution. Employed bee updates its position by using Eq. (12) and it updates new position if it is better than the previous position, i.e. it follows greedy selection. [9]

$$Vij = Xij + Rij\,(Xij - Xjk) \quad (12)$$

where, Vij is the new position of employed bee, Xij is the current position of employed bee, k is random number between (1, (population size)/2) = i and j =1, 2,…, Number of design variables.Rij is a random number between (-1, 1).An onlooker bee chooses a food source depending on the probability value associated with that food source, Pi, calculated by using

$$Pi = p/sum(pi) \quad (13)$$

where, Pi is the fitness value of the solution i and N/2 is the number of food sources which is equal to the number of employed bees. Onlooker bees also update its position by using Eq.(13)and also follow greedy selection. The Employed bee whose position of the food source cannot be improved for some predetermined number of cycles than that food source is called abandoned food source. That employed bee becomes scout and searches for the new solution randomly by using the equation

$$Xij = Xijmin + rand(Xijmax - Xijmin) \quad (14)$$

The value of predetermined number of cycles is an important control parameter of the ABC algorithm, which is called ‘‘limit’’ for abandonment. The value of limit is generally taken as Number of employed bees*Number of design variables.

4.5. Hybrid Perturb and Observe Method

Usually hybrid approaches enumerated better results than the conventional methods [12-13]. Normally perturb and observe method is used in standard conditions and it is not high efficient one for drastically changing environmental conditions but under non irradiance and abnormal conditions the optimization algorithms had recorded the better outcomes, so in this work the perturb and observe method which is a conventional method and the optimization algorithm like PSO and ABC are collectively used to track the maximum power point to operate the panel for getting maximum power under different conditions like constant irradiation and temperature or different irradiation and constant temperature .The tracking performance of the maximum power also very high when compared to the conventional method. The following flow chart.Figure.7. describes the implementation method of hybrid perturb and observe method.

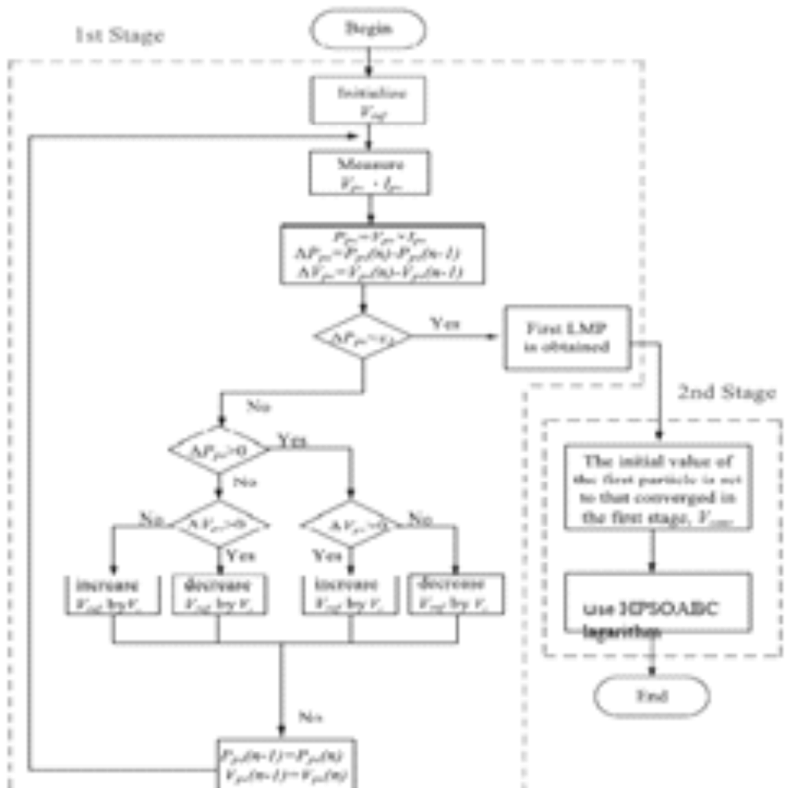

Figure 7: Hybrid perturb and observe Algorithm HPO [9]

Together ABC and PSO are worthy enough to explore the search space. HPO is developed to combine the advantages of both ABC and PSO. HPO starts with the initial population and updates the solution by following the searching mechanism of the employed bees in ABC. The solutions obtained after the employed bee phase follows the mechanism of particle swarm optimization. From the above flow chart the hybrid perturb and observe algorithm also prepared and it is useful to write the program in MATLAB Environment.

In the first stage it is same as conventional P and O method if it exceeds the value of α it moves to second stage, α depends on |Δpvbest-Δpv| . It is observed from this method there is only a little increase in the computational effort of HPO as compared to basic ABC.[9] However, HPO eliminates the proportional selection for the onlooker bees and also the scout bees. Solution is updated after the employed bee phase by following the search mechanism based optimization and hence it combines the strength of both the algorithms.

V. RESULTS AND DISCUSSIONS

Perturb and Observe, Modified Perturb and Observe, Hybrid Perturb and Observe Methods were simulated for grid connected solar PV system through MATLAB/SIMULINK environment which is shown in Figure.8.For this Sun Power SPR-305-WHT solar panels were used. Each module consists 96 cells, 5 modules are connected in series as a string and 20 strings are connected in parallel. Each module approximate power is 220W and the array generated power is 20KW.

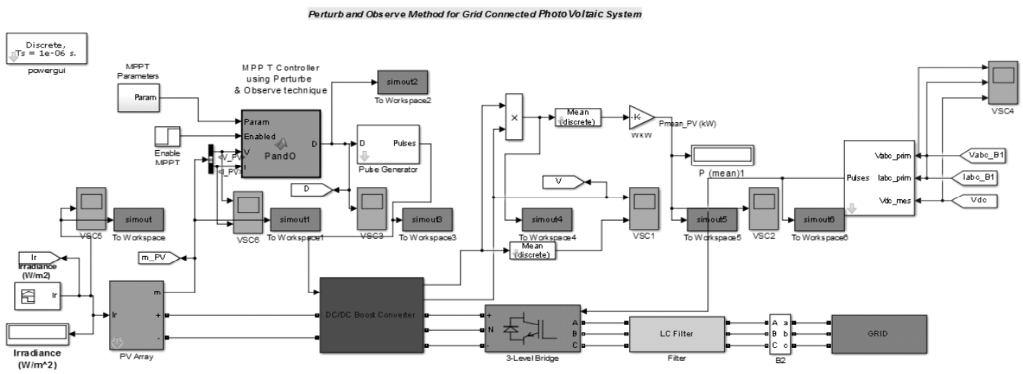

Figure 8: Simulink Model of Grid connected Photo Voltaic system with MPPT methods

5.1. Performance analysis

In this subsection, the performance evaluations of the proposed system were carried out through the above SIMULINK model and the simulation results were collected from Figure8. The performance analysis were carried out under constant irradiation and temperature, different irradiation and constant temperature, constant irradiation and different temperatures as case studies.

Case 1: Analysis of power under Constant irradiance and temperature

The proposed Hybrid Perturb and Observe algorithm. was used to control the MPPT while converter circuit predicts the voltage and current in order to have the optimal sinusoidal waveform. This system was simulated to

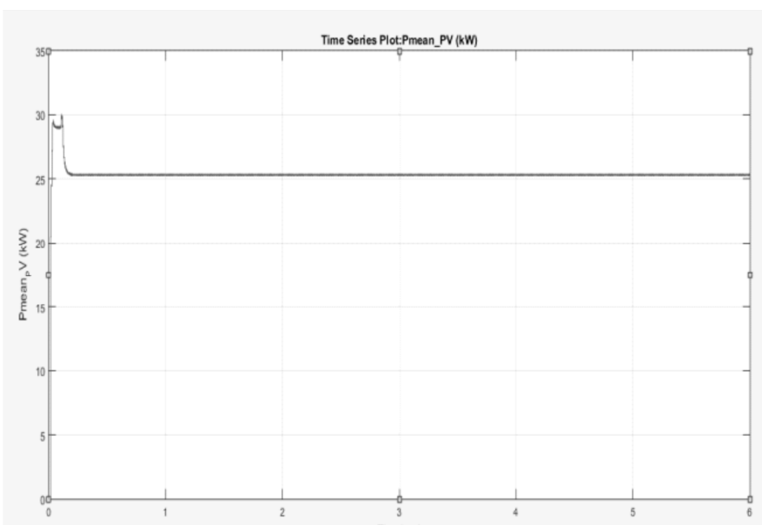

Figure 9: Power response of Perturb and observe

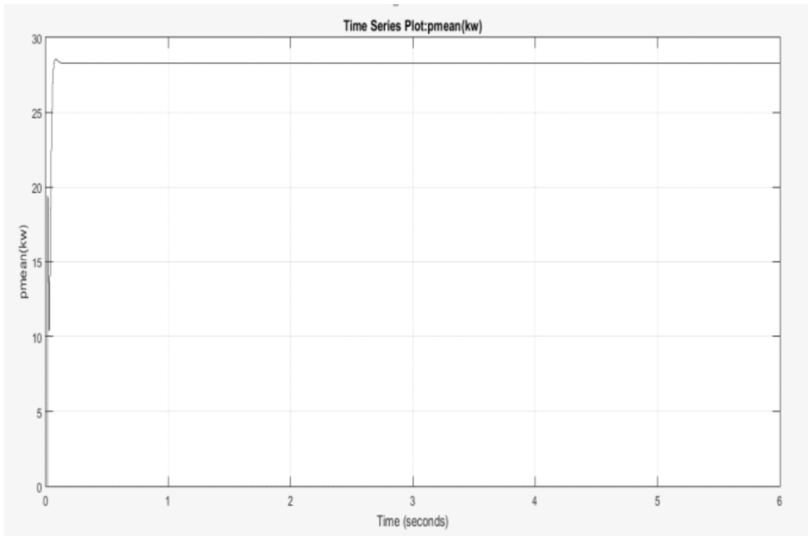

Figure 10: Power curve of Modified perturb & observe

learn the operation of the PV-grid connected system. Here the proposed method is compared with the existing methods such as P&O technique, Modified Perturb and Observe Method and the results were shown in the following graphs and values are tabulated in the table form.

In Fig. 9. the X-axis indicates time in seconds, Y-axis is Power in Kilowatts .In the above graph average mean power was noted as 25kW after reaching steady state and it took 0.3sec time to reach the steady state. From above Fig. 10. it is observed that the mean power is improved to 28KW after reaching steady state. The time taken to reach steady state is 0.2sec. here also the scale, on X-axis time in seconds and on Y-axis Pmean in kilowatts is noted.

From the Fig.11.it is observed that the output mean power incremented to 30KW and it reached steady state before 0.2sec.Scale here on X-axis is time in seconds and on Y-axis Pmean in kilowatts. The complete analysis and the comparison of the methods were tabulated in the Table 2.

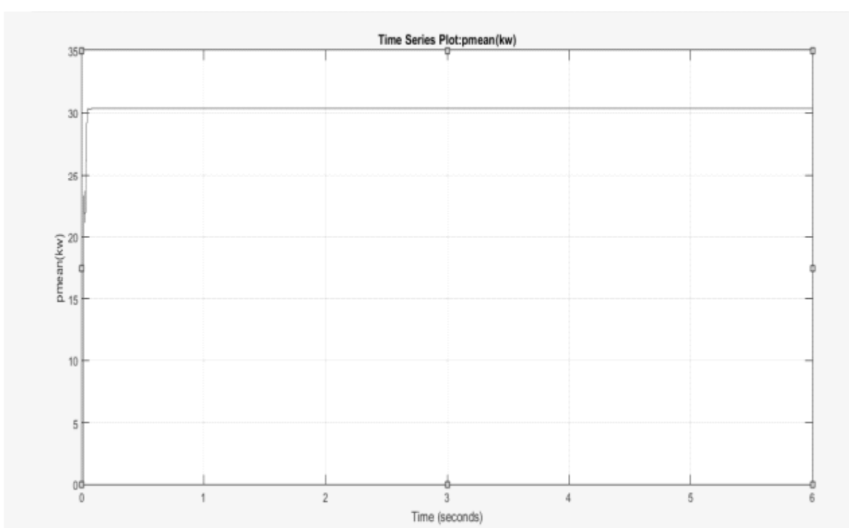

Figure 11: Power response of Hybrid Perturb & observe

Table 2
Comparison of power for case 1

MPPT Methods	*Pmean (KW) at 1000 W/m2 and 25°C temperature*	*Convergence time (seconds)*
Perturb & observe	25	0.3
Modified perturb &Observe	28	0.2
Hybrid perturb &observe	30	0.1

Case 2: Analysis of power under different irradiance and temperatures

In Fig. 12. scale on X-axis is time in seconds and on Y-axis Irradiance and temperature is mentioned respectively. The Fig. 12. represents the input signals to the solar panel for total simulation time 6sec.

It is observed that ,from above Fig.12. that the irradiance levels changes from 1000 W/m2 to 250 W/m2. in the time interval t=0 to t=2 sec, from t=2 to t=5sec it is observed that variation in the temperature from 25°C to 50°C again drops to 22°C.Using above irradiance and temperature signals power of various Perturb and observe algorithms was observed and compared .In Fig.13.scale is ,on X-axis time in seconds and on Y-axis mean power in kilowatts is mentioned. From the above Fig.13. it is monitored that, due to variation in irradiance levels the mean power drops from 25KW to 4KW and in case of temperature variation 25°C to 50°C power drops to 3KW.

From Fig. 14. It is observed that the mean power becomes gradually decreased when compared to normal irradiance conditions that are from 28KW to 7KW and in case of temperature variation 25 to 50°C power drops to 13KW.Here on X-axis time in seconds and on Y-axis Pmean Power in kilo watts is mentioned respectively.

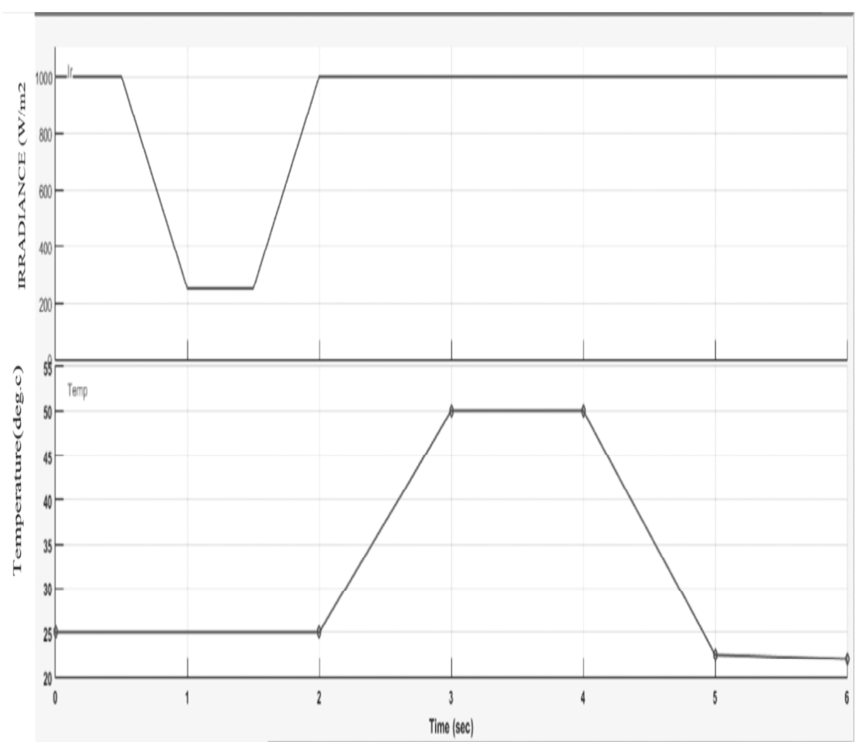

Figure 12: Input variables Irradiance and Temperature

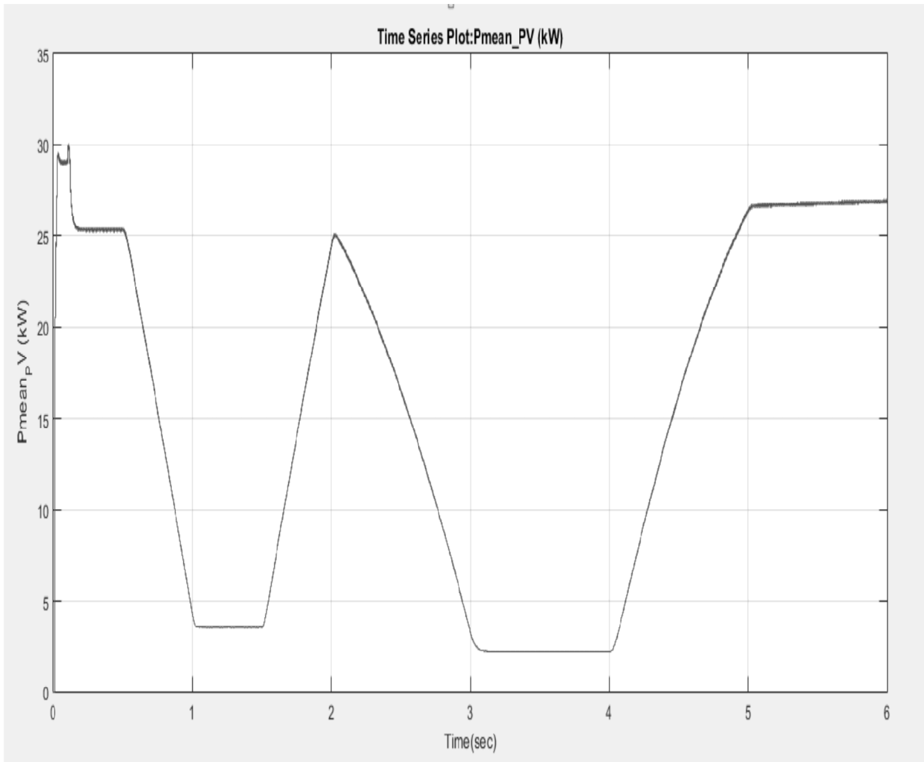

Figure 13: Power curve of Perturb and observe

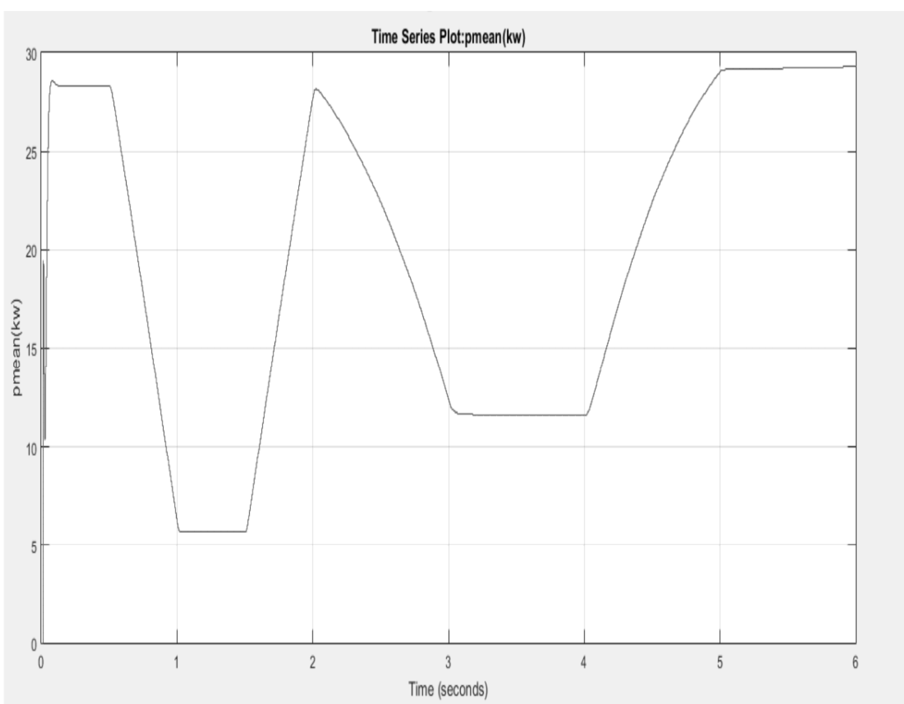

Figure 14: Power curve of modified perturb & observe

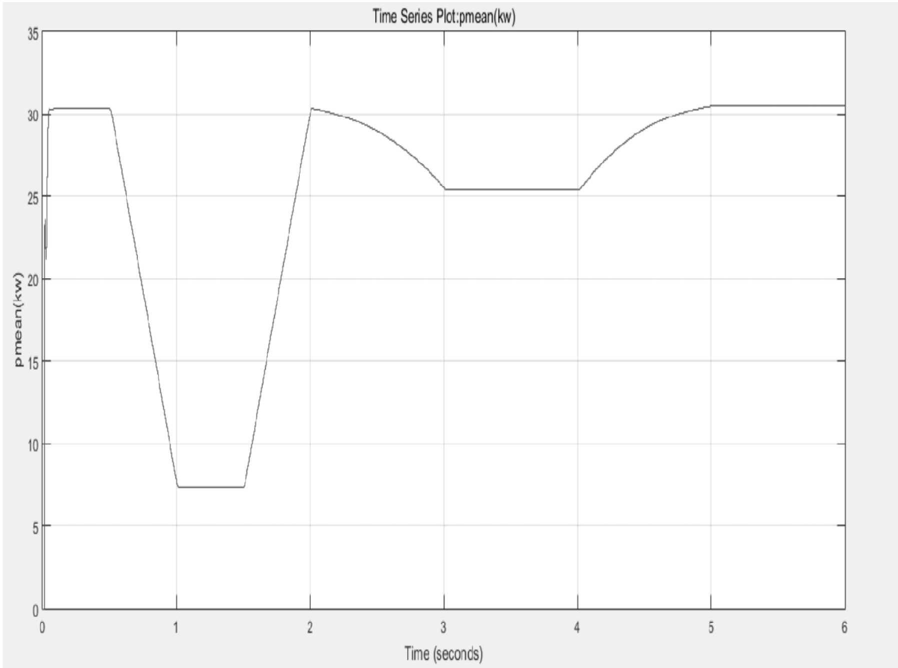

Figure 15: Power curve of hybrid perturb & observe

From the Fig.15. It is monitored that, due to variation in irradiance levels the mean power drops from 30KW which is obtained in the normal and constant irradiance conditions to 8KW and in case of temperature variation 25 to 50°C power drops to 23KW.Scale on X-axis is time in seconds and on Y-axis mean power in kilowatts is mentioned respectively. The complete analysis of the case.2 was tabulated in the table.3.

Table 3
Comparison of power for case 2

Various conditions	*Techniques*	*Power (KW)*
1000 W/m2 at 25°C	Perturb and observe method	25
	Modified perturb and Observe method	28
	Hybrid perturb and Observe method	30
400 W/m2 at 25°C	Perturb and observe method	10
	Modified perturb and Observe method	12
	Hybrid perturb and Observe method	14
250 W/m2 at 25°C	Perturb and observe method	4
	Modified perturb and Observe method	7
	Hybrid perturb and Observe method	8
1000 W/m2 at 35°C	Perturb and observe method	18
	Modified perturb and Observe method	22
	Hybrid perturb and Observe method	29
1000 W/m2 at 45°C	Perturb and observe method	10
	Modified perturb and Observe method	12
	Hybrid perturb and Observe method	22
1000 W/m2 at 50°C	Perturb and observe method	3
	Modified perturb and Observe method	13
	Hybrid perturb and Observe method	23

VI. CONCLUSION

In this paper the Hybrid Perturb and Observe technique is used for tracking the maximum power of PV system. The proposed MPPT controller design has input panel voltage and current. The output of proposed method was evaluated and analyzed to achieve the maximum power from the PV. The dynamical performances and the robustness of the proposed method are also evaluated. The performance of the proposed method is compared with the existing methods, such as, P&O, Modified Perturb and Observe. Moreover it is proven that the proposed controller is robust for the different cases which are having different input solar irradiance conditions. The deviation rate of tracking performances of the proposed method is compared with the remaining used methods. The maximum power of the proposed method and existing techniques are tracked and analyzed. The simulation results proved that the proposed controller overcomes the disturbances in the power curve with maximum power attained as 30KW, which is the maximum compared to the other methods. And it also taken less time to track the maximum power.

REFERENCES

[1] Wu TF, Chang CH, Liu ZR, Yu TH. Single-stage converters for photovoltaic powered lighting systems with MPPT and charging features. In: Proc. IEEE APEC;, pp. 1149–1155, 1998.

[2] De Broe AM, Drouilhet S, Gevorgian. V. A peak power tracker for small wind turbines in battery charging applications. IEEE Transactions on Energy Conversion 1999; 14(4): 1630–5.

[3] M. Ameli, S. Moslehpour, and M. Shamlo, “Economical load distributionin power networks that include hybrid solar power plants,” *Elect.Power Syst. Res.*, vol. 78, no. 7, pp. 1147–1152, 2008.

[4] Bahgat ABG, Helwab NH, Ahmadb GE, El ShenawybET. Maximumpower point tracking controller for PVsystems using neural networks. Renewable Energy 2005; 30: 1257–68.

[5] SalasV, Olı _as E,Barrado A. ALazaro Review of the maximum power point tracking algorithms for stand-alone photo voltaic systems. Solar Energy Materials & Solar Cells 2006; 90: 1555–78.

[6] Esram T., Chapman PL. Comparison of photovoltaic array maximum power point tracking techniques. IEEE Transactionson Energy Conversion 2007; 22: 2.

[7] Habbati Bellia a,*, Ramdani Youcef b, Moulay Fatima b “A detailed modeling of photovoltaic module using MATLAB”, a Universite Bechar, Algeria,b Universite Sidi-Bel-Abbes, Algeria, Available online 16 May 2014, NRIAG Journal of Astronomy and Geophysics (2014) 3, 53–61.

[8] Mohammed El-Abd *Computer Engineering, American University of Kuwait,* “On the hybridization of the artificial bee colony and particle swarm optimization” JAISCR, 2012, Vol. 2, no. 2 pp 147-155.

[9] Advanced Optimization Techniques.

[10] Awang Bin Jusoh*1, Omer Jamal Eldin Ibrahim Mohammed2, Tole Sutikno3" Variable Step Size Perturb and Observe MPPT for PV Solar Applications”

[11] B. R. Peng, J. H. Chen, Y.H. Liu, Y.H. Chiu ‘Comparison between Three Different Types of Variable Step-Size P&O MPPT Technique”.

[12] S. Saravanan, Ramesh Babu N’ Maximum power point tracking algorithms for photovoltaic system – A review’ Renewable and Sustainable Energy Reviews 57 (2016) 192–204.

[13] Eftichios Koutroulis & Frede Blaabjerg’Overview of Maximum Power Point Tracking Techniques for Photovoltaic Energy Production Systems’25 August 2015, Electric Power Components and Systems Taylor & Francis.