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MAXIMUM POWER POINT TRACKING OF A PV SYSTEM BY BACTERIA FORAGING ORIENTED PARTICLE SWARM OPTIMIZATION

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ABSTRACT: This paper proposes a Bacteria Foraging oriented by Particle Swarm Optimization algorithm(BF-PSO) with open circuit voltage maximum power point tracking (MPPT) method is used to track the maximum power for the photovoltaic (PV) system. The proposed method has ability to track the maximum power point (MPP) for different insolation levels and maintains the constant output voltage. In this, MPPT is employed in conjunction with the boost converter, where boost converter is used to rise the voltage generated by PV module to required voltage level. The implementation of this proposed algorithm is very simple and performs quick calculations. At the end, the effectiveness of the proposed BF- PSO is compared with 'without MPPT' and highlighted by simulation results.

INDEX TERMS: Photo voltaic (PV) system, maximum power point tracking (MPPT), bacteria foraging (BF), particle swarm optimization (PSO), bacterial foraging –particle swarm optimization (BF-PSO), Boost Converter.

I. INTRODUCTION

Energy crisis over the last decades and environmental problems gives great attentions on energy management. This paper deals with one of the renewable energy source like solar photovoltaic (PV) system, which is predicted to be a popular source due to numerous advantages, especially low maintenance, operational cost and no emission of harmful gases, hence environmentally friendly[1-4]. These PV systems directly give electrical energy from solar energy without into other energy conversion, thereby efficiency of the solar PV system is high. The challenge in PV system is tracking of maximum efficiency, due to climate changing. In this paper maximum power point tracker (MPPT) is generally used with dc–dc converter to set the maximum power point. To optimize the utilization of large PV arrays or modules , MPPT is normally employed in conjunction with the power converter[1].This tracking technique is needed in solar power generation due to non linear I-V characteristics of solar cell.

In general there are several MPPT methods[5] are there but they are different in various aspects and controlling variables such as voltage, current and firing angle. 1) Perturb & Observe method (P&O), this method introduce some perturbation and maintain operating point around maximum point and but the only disadvantage with this method is it can't track MPP under fast shading conditions, 2) Incremental conductance method, which evaluates the proportion of derivative of conductance with the instant conductance, 3) short circuit current method will calculate I_{MP} based on I_{SC} similarly 4) Open circuit voltage method, this method will calculate V_{MP} based on $V_{OC.}$ However in all these before mentioned algorithms the open circuit voltage method has some advantages such as simple structure and less cost. Due to these advantages of open circuit voltage method, the evolutionary algorithm is combined with this method to get MPP with reduced steady state oscillation.

In the next generation artificial intelligence approach such as fuzzy logic and neural network has proposed by the researchers to overcome the drawbacks of conventional methods. Although these methods are suitable for dealing nonlinear *I–V* characteristics of solar PV module, they necessitates wide calculations and also implementation of low-cost processor is not possible with this proposed method[6]. An evolutionary algorithm (EA) approach is the new advanced technique to deal nonlinear objective functions. There are several EA's such as genetic algorithm (GA) and Particle Swarm Optimization (PSO), etc. In this paper BF-PSO is proposed with the combination of BF and PSO as it can deal MPPT very effectively due to its simple structure, fast computation capability and easy implementation[7-8].

The research gap has been found in this area is that no researcher has combined PSO with BF, hence eliminates the steady-state oscillations generally exist in conventional MPPT methods. Finally this paper concludes that by applying this proposed BF-PSO, the system has fewer oscillations at MPP and can effectively track the MPP for large change in insolation. Another advantage of this proposed method over conventional MPPT techniques is, it has a faster tracking speed.

The remainder of this paper is organized as follows. Section II discusses the modeling of the PV cell and PV module based on work published in[9-10].This would be basis for the simulation work. In section III, Open circuit voltage method is briefly explained. Section IV describes the over view of PSO, BF and BF-PSO[11]. In this dc to dc boost converter is used for rise the module output voltage. Section V describes the simulation results. Finally the conclusion is made in last section.

II. MODELING OF PV CELL AND PV MODULE

A. Modeling of a PV Cell

The simplest model of a PV cell is shown in fig.1 as an equivalent circuit below that consists of an ideal current source in parallel with an ideal diode. The current source represents the current generated by photons (often denoted as I_{ph} or I_L), and its output is constant under constant temperature and constant incident radiation of light.

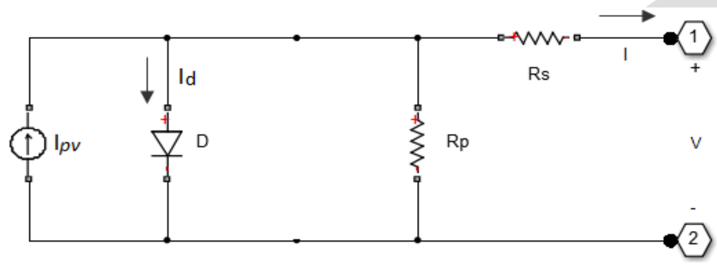

Fig.1: Single-diode model of a PV cell.

The output current equation can be expressed as follows

$$I = I_{PV} - Id - \left(\frac{V + IR_S}{R_P}\right) \quad (1)$$

Where,

$$Id = I_o\left[\exp\left(\frac{V + IR_S}{aV_T}\right) - 1\right] \quad (2)$$

The two-diode model of the PV cell has been modeled in this project due to its more accuracy compared to single diode model and is illustrated in Fig.2.The output current equation can be expressed as follows

$$I = I_{PV} - I_{d1} - I_{d2} - \left(\frac{V + IR_S}{R_P}\right) \quad (3)$$

Where,

$$I_{d1} = I_{01}\left[\exp\left(\frac{V + IR_S}{\alpha_1 V_{T1}}\right) - 1\right] \quad (4)$$

And $I_{d2} = I_{02}\left[\exp\left(\frac{V + IR_S}{\alpha_2 V_{T2}}\right) - 1\right]$ (5)

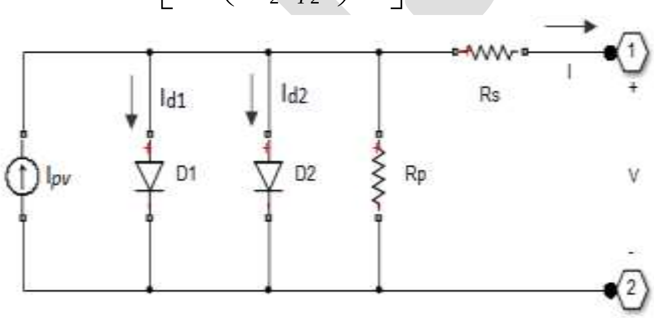

Fig.2: Two-diode model of a PV cell.

Where I_{PV} is the Photon current generated by the incidence of light; and I_{o1} and I_{o2} are the reverse saturation currents of diode 1 and diode 2 respectively. The I_{o2} term is introduced to compensate for the recombination loss in the depletion region. V_{T1} and V_{T2} (both are equal to kT/q) are the thermal voltages of the PV cell, q is the electron charge(1.602×10^{-19} C), *k is the B*oltzmann constant(1.38×10^{-23} J/K), and T is the p-n junction temperature in Kelvin. Variables a_1 and a_2 are ideal factors of diode1 and diode2 respectively. The developed current equation is for two-diode model has been presented in following equations given by

$$I = I_{PV} - I_0\left(I_P + 2\right) - \left(\frac{V + IR_S}{R_P}\right) \tag{6}$$

Where

$$I_P = \exp\left(\frac{V + IR_S}{V_T}\right) + \exp\left(\frac{V + IR_S}{(P-1)V_T}\right) \tag{7}$$

And $P = 1 + a_2$ (8)

B. Modeling of a PV Module

The modeling of aPV module is as same as PV cell modeling but here we are taking 72 solar cells connected in series. A single PV cell produces an output voltage less than 1V, about 0.6V for crystalline-silicon (Si) cells, thus a number of PV cells are connected in series to achieve a desired output voltage. When series-connected cells are placed in a frame, it is called as a module. Most of commercially available PV modules with crystalline-Si cells have either 36 or 72 series-connected cells. A 36-cell module provides a voltage suitable for charging a 12V battery, and similarly a 72-cell module is appropriate for a 24V battery.

TABLE I

Parameters of the BPSX-150 PV module at stc: temperature = 25 ◦c, insolation = 1000w/m2

Electrical Characteristics	Rating
Maximum Power (P_{max})	150W
Voltage at P_{max} (V_{mp})	34.5V
Current at P_{max} (I_{mp})	4.38A
Open-circuit voltage (V_{OC})	43.5V
Short-circuit current (I_{SC})	4.75A
Temperature coefficient of I_{SC}	0.065 ± 0.015 %/ ^{o}C
Temperature coefficient of V_{OC}	-160 ± 20 mV/ ^{o}C
Temperature coefficient of power	-0.5 ± 0.05 %/ ^{o}C

Fig.3 shows the I−V curves of a PV module for different number of cells,fig.4 shows I−V curves of a PV module for different irradiation levels, fig.5 shows P−V curves of a PV module for different irradiation levels, and fig.6 shows I-V and P-V curves for commercial PV module(BPSX-150).The parameters of this particular module under the standard test condition (STC) are shown in Table I.

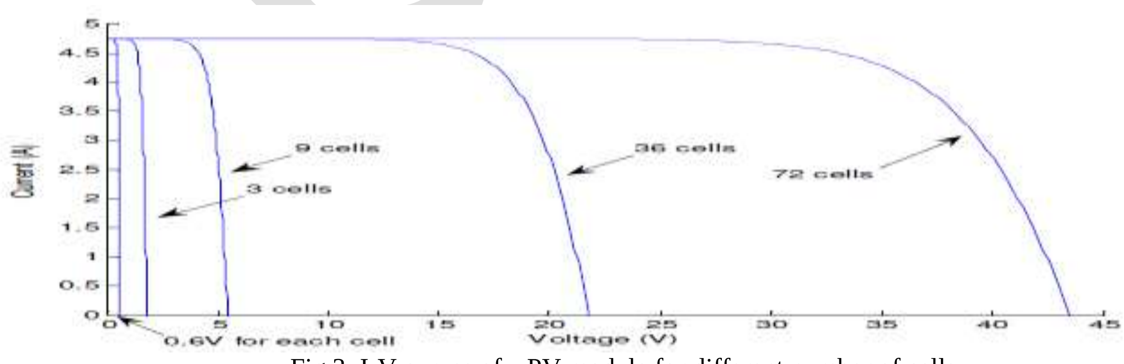

Fig.3: I-V curves of a PV module for different number of cells

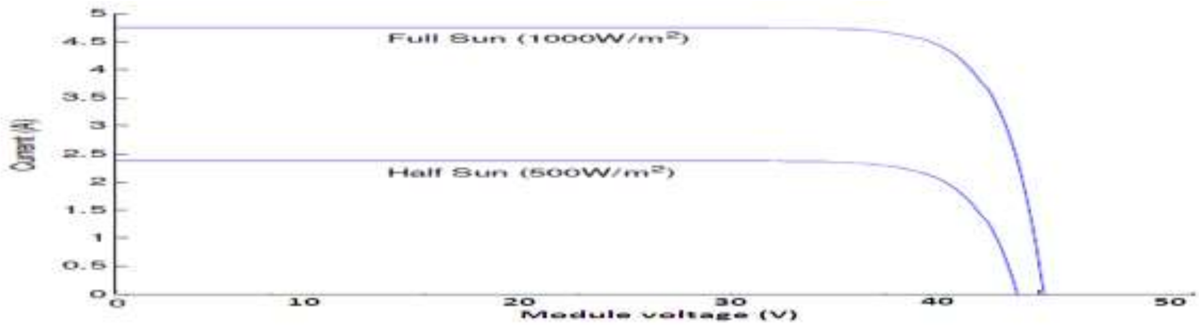

Fig.4: I-V curves of a PV module for different irradiation levels

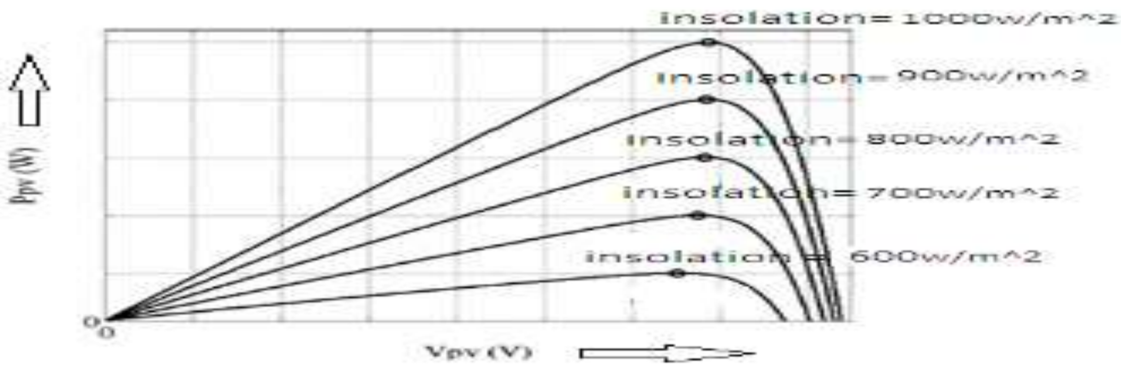

Fig.5: P-V curves of PV module for different irradiation levels

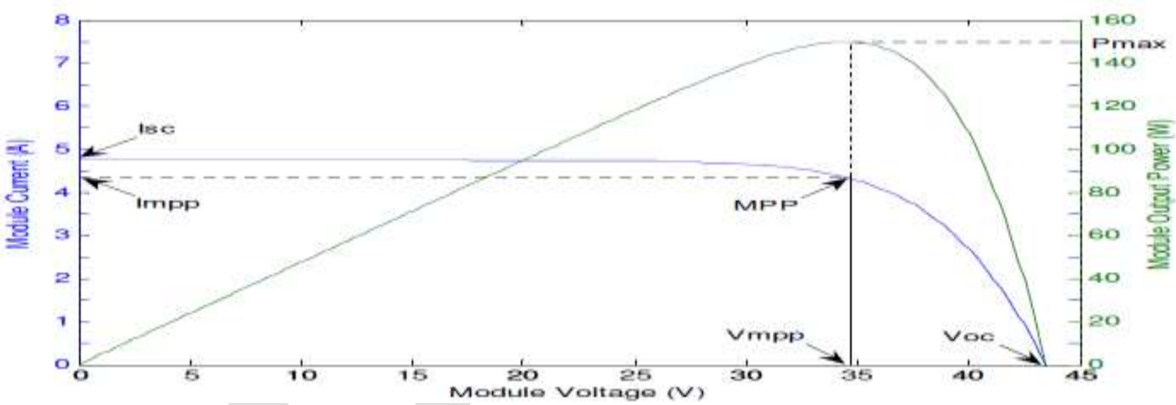

Fig.6: I-V and P-V curves of a BPSX 150PV module

III. OPEN CIRCUIT VOLTAGE METHOD

In general there are so many MPPT methods are existed. In this paper Open circuit voltage method is proposed over afore mentioned methods, because of its advantages such as simple structure and less cost due to one sensor.The flow chart of open circuit voltage method for mppt is shown in fig.7. In this method the maximum tracked voltage is given by

$$V_{MPP} = K * V_{OC} \qquad (9)$$

Where V_{MPP} is maximum voltage, V_{OC} is open circuit voltage and K is constant and the range of K is 0.73 to 0.8 for polycrystalline PV module.

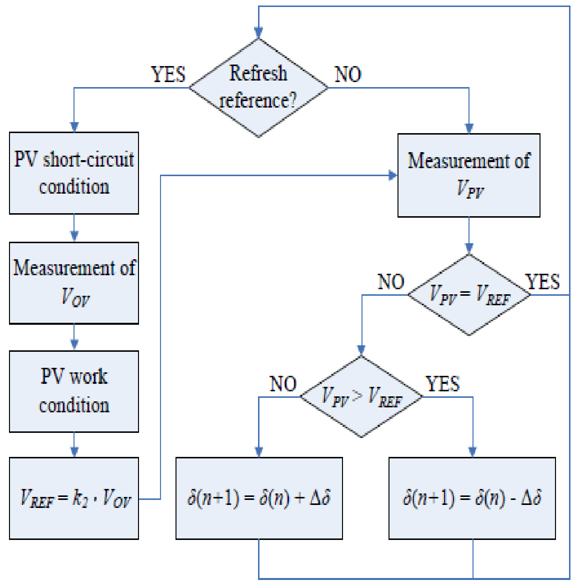

Fig.7: Flowchart of the open circuit voltage method

IV. BF- PSO BASED MPPT

A. Basic Particle Swarm Optimization (PSO)

The PSO model consists of swarm of particles, which are initialized with a population of random candidate solutions. They move iteratively through the d-dimension problem space to search the new solutions. Each particle has a position represented by a position vector X_k^i where i is the index of the particle and velocity represented by a velocity vector V_k^i . Each particle remembers its own best position P_{Lbest}^i . The best position vector among swarm then stored in a vector P_{Gbest}^i . During the iteration time k, the update of the velocity from the previous velocity to the new velocity is determined by

$$V_{k+1}^i = V_k^i + C_1 R_1 \{P_{Lbest}^i - X_k^i\} + C_2 R_2 \{P_{Gbest}^i - X_k^i\} \qquad (10)$$

The new position is then determined by the sum of the previous position and new velocity

$$X_{k+1}^i = X_k^i + V_{k+1}^i \qquad (11)$$

Where C_1 and C_2 are acceleration coefficients, R_1 and R_2 are random numbers. A particle decides where to move next, considering its own experience of the most successful particle in the swarm.

B. Basic Bacterial Foraging optimization(BF)

The selection behavior of bacteria tends to improve successful foraging strategies and eliminate poor foraging strategies. The E-coli bacteria has a control system that enables it to search for food. The distribution of bacteria motion can be modeled as following four stages.

B.1 Swarming and Tumbling(N_S)

The flagellum is a left-handed helix configured so that as the base of the flagellum (i.e . where it is connected to the cell) rotate counterclockwise, as shown in below figure.

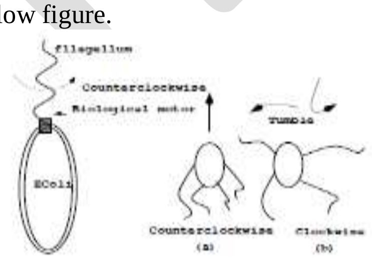

Fig.8: E-coli bacteria while it is swimming and tumbling

From the free end of the flagellum looking toward the cell, it produces a force against the bacterium then pushing the cell. This mode of motion is called swimming. Bacteria swims either for maximum number of steps N_s or less i.e. depending on the concentration of nutrition and condition of environment. But if the flagellum rotate clockwise each flagellum pulls on the cell as shown in fig.8(b) , so that the net effect is that each flagellum operates relatively independently of the others and so the bacterium tumble . Tumbling mode indicates a change in the future swim direction.

B.2 Chemotaxis (N_C)

A set of consequence swim steps following by tumble is called chemotaxis step . A maximum of swim steps with a chemotactic step is predefined by N_S. The actual number of swim steps is determined by the environment. If the environment shows good concentration OF nutrients in the direction of the swim, the (E- coil) bacteria swim more steps. The end of the chemotactic step is determined by either reaching the maximum number of steps N_S or poor environment. When the swim steps is stopped a tumble action takes place.
To represent a tumble, a random unit length vector with direction delta(n,i) is generated. Where j be the index for the chemotactic step,i is the index of bacterium that has the maximum number of bacteria S . This vector is used to define the direction of movement after a tumble. Let c(i) > 0 i=1,2,……,S denote a basic chemotactic step size that we will use to define the lengths of steps during runs. The step size is assumed to be constant. The position of each bacterium is denoted by p(n,i,j,k,ell) where n is the dimension of search space, k is the index of reproduction step and ell is the index of elimination-dispersal events. The new bacterium position after tumbling is given by.

$$P^{i}_{n,j+1,k,ell} = P^{i}_{n,j,k,ell} + Delta(n,i) * c(i) \quad (12)$$

B.3 Reproduction(N_{re})

A reproduction step is taken after N_C chemotactic steps. Let N_{re} be the number of reproduction steps to be taken. For convenience, we assume that S is a positive even integer. Let

$$S_r = \frac{S}{2} \quad (13)$$

be the number of population members who have had sufficient nutrients so that they will reproduce (split in two) with no mutations. For reproduction, the population is sorted in order of ascending accumulated cost (higher accumulated cost represents that it did not get as many nutrients during its lifetime of foraging and hence, is not as “healthly” and thus unlikely to reproduce). The S_r healthiest bacteria each split into two bacteria, which are placed at the same location.

B.4 Elimination and Dispersal(N_{ed})

Elimination event may occur for example when local significant increases in heat kills a population of bacteria that are currently in a region with a high concentration of nutrients. A sudden flow of water can disperse the bacteria from one place to another. The effect of elimination and dispersal events is possibly destroying chemotactic progress, but they also have the effect of assisting in chemotaxis, since dispersal may place bacteria near good food sources.

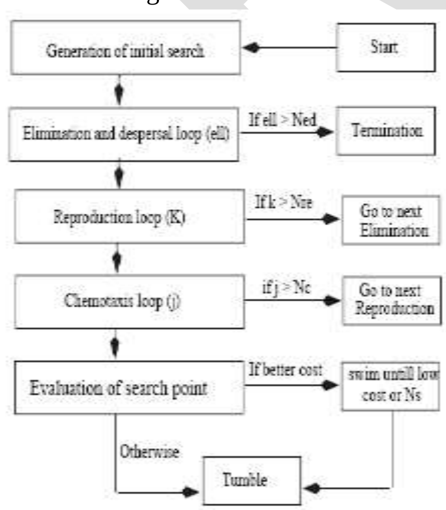

Fig.9: Bacteria Foraging algorithm flowchart

C. Bacterial Foraging optimization oriented by Particle Swarm Optimization (BF-PSO)

The BF-PSO combines both algorithms BF and PSO. This combination aims to make use of PSO ability to exchange social information and BF ability in finding a new solution by elimination and dispersal. In this project BF-PSO method reduces the error(which is produced by comparing the output voltage with its reference), gives constant voltage and changing the dynamic characteristics of PV system to tracks maximum power always.

For initialization, the user selects n, S, S_r , N_s, N_c, N_{re}, N_{ed}, P_{ed}, C_1, C_2,R_1, R_2 and c(i), i=1,2,3….S. Also initialize the position $P^i_{n,1,1,1}$,i=1,2,3,….S and velocity randomly initialized.

Where n is dimension of search space, S is the number of becteria in the population, S_r is the half of the total bacteria, N_s is the maximum number of swim length, N_c is the number of chemotactic steps, N_{re} is the number of reproduction steps, N_{ed} is the number of elimination and dispersal steps, P_{ed} is the elimination and dispersal with probability, c(i) is the step size taken in the random direction, C_1,C_2 are the PSO random parameters and R_1,R_2 are the PSO random parameters.

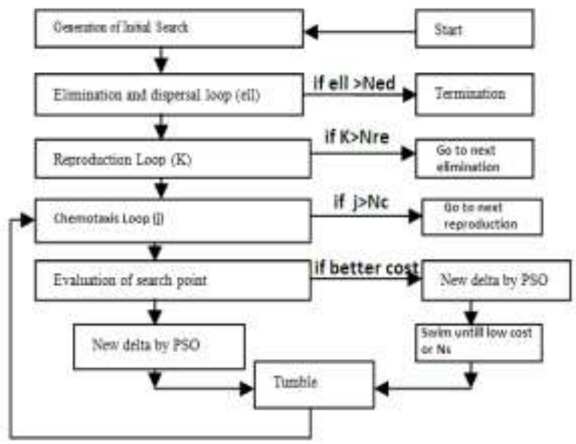

Fig.10: Bacteria foraging oriented by PSO algorithm flowchart

This algorithm produces the globally best values of Kp,Kd and Ki for PID controller in PV system by iterative process to get MPP for PV system with constant voltage.

V. SIMULATION CIRCUIT AND RESULT ANALYSIS

The Fig.11 shows the MATLAB-Simulink simulation model of the PV system used in this study. The dc to dc boost converter is used to step up the dc voltage to our requirement and has an advantage i.e. it reduces the usage of PV modules. The converter is designed for continuous inductor current mode with following specifications: L=80μH, C=20.8μF and 20KHZ switching frequency. The utilized PV module is the BPSX-150. The key specifications of the module are shown in Table- I.

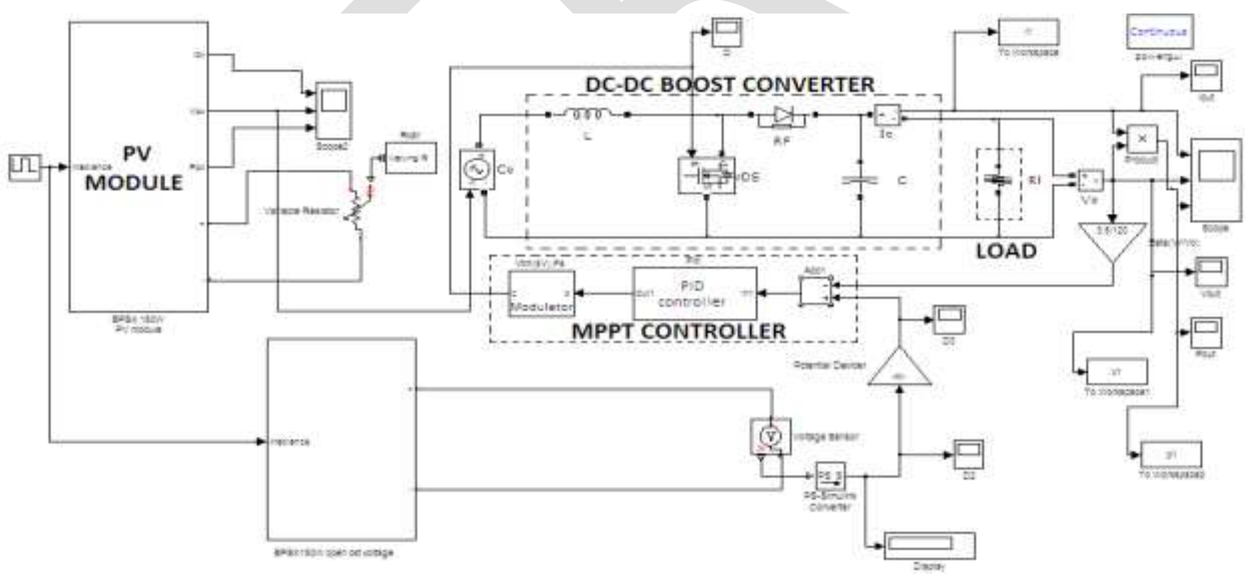

Fig.11: MATLAB-Simulink model for the PV system with the boost converter and proposed MPPT controller

The voltage given by the solar PV array is variable and is of low magnitude. To provide a constant and high magnitude of voltage a MPPT based DC - DC boost converter is used. In order to obtain maximum power from the solar PV module MPPT technique is used. DC power from the boost converter is given to a load.

For the case of uniform change in insolation, the insolation is stepped from low to high, step down from high to low, and stepped to high again. The initial level is set at 700w/m^2 , at t=0.2s, the insolation is suddenly stepped up to 1000w/m^2, and at t=0.4s, the insolation is stepped down to 700w/m^2 .

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Fig.12 shows the simulation results for current, voltage and power respectively obtained by using without MPPT method. In this method, at t=0s the tracked power is 65w for 700w/m^2 insolation, at t=0.2s the tracked power is 130w for 1000w/m^2 insolation, and at t=0.4s the tracked power is 65w for 700w/m^2 insolation. By observing the waveforms we noticed that,the output voltage is not maintained constant for different insulation levels, so the connected load will not work properly and also noticed that the tracked power is not maximum, so the efficiency of PV system is less.

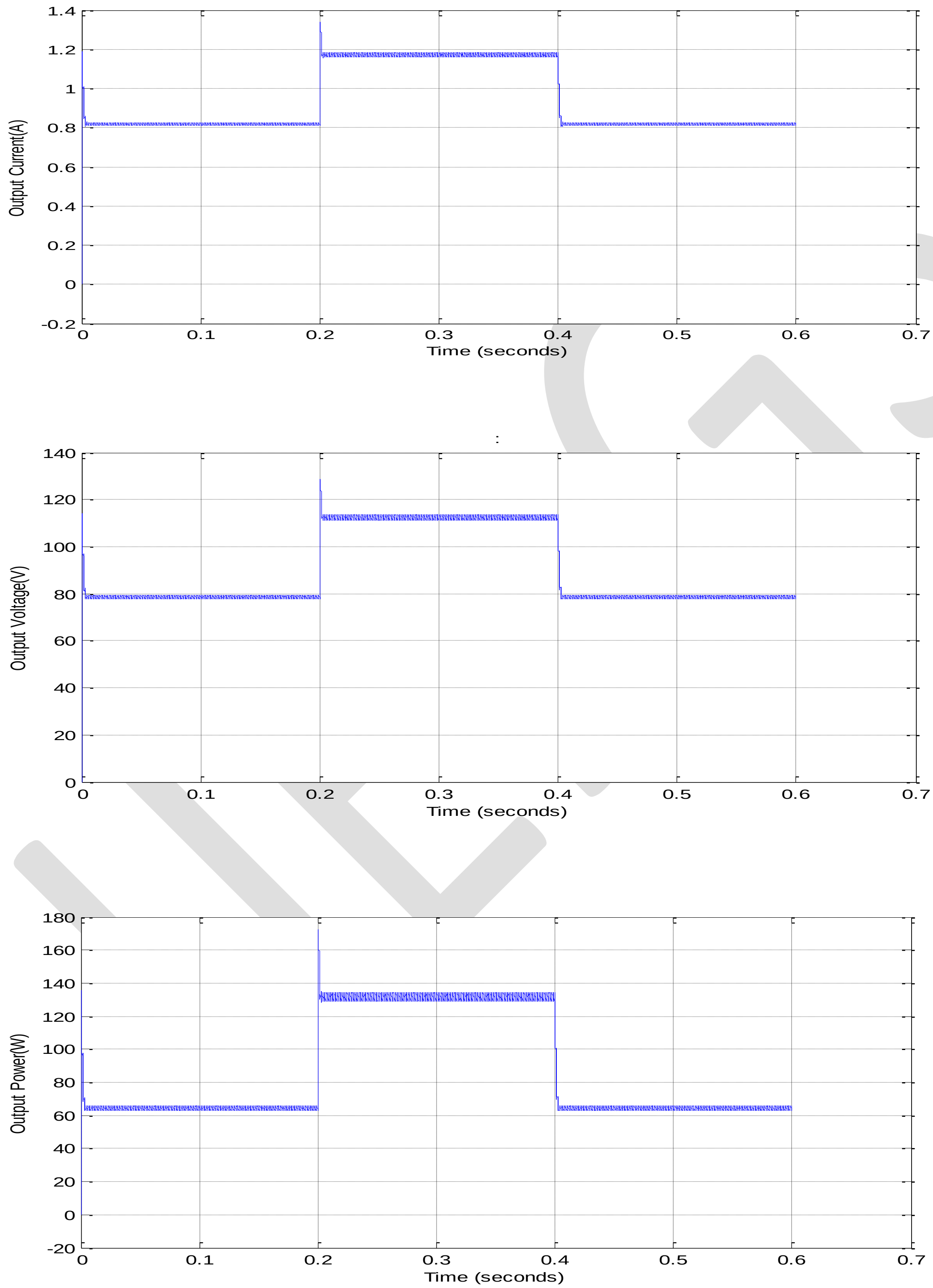

Fig. 12: Tracking output current, output voltage and output power waveforms by Without mppt method

Fig.13 shows the simulation results for current, voltage and power respectively obtained by using proposed BF-PSO MPPT method. In this method at t=0s the tracked power is 140w for 700w/m^2 insolation, at t=0.2s the tracked power is 150w for 1000w/m^2 insolation, and at t=0.4s the tracked power is 140w for 700w/m^2 insolation. By observing the waveforms we can say that, the output voltage is nearly maintained constant so no problem about connected load and also we can say that, the tracked power is maximum so the efficiency of PV system improved.

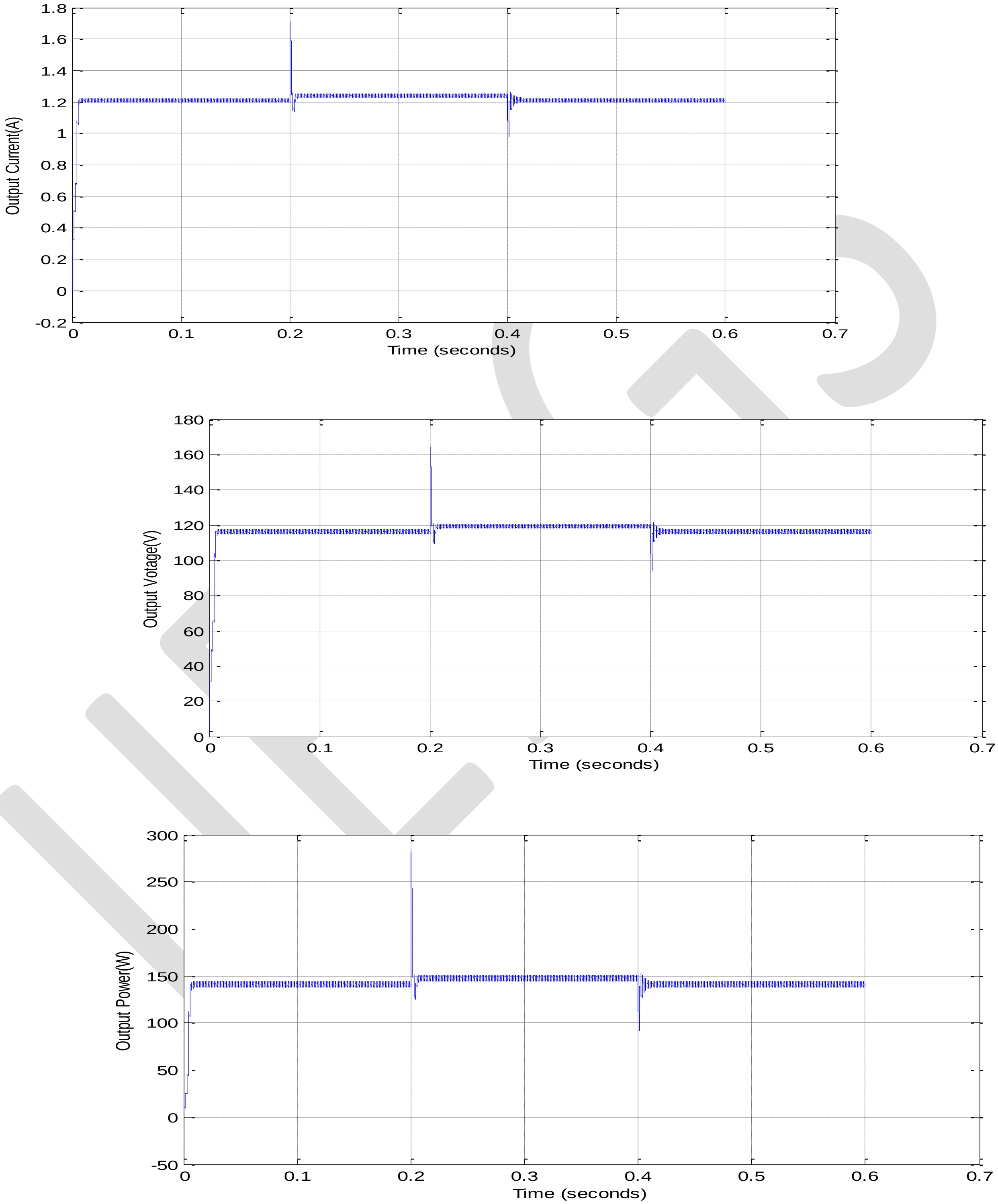

Fig. 13: Tracking output current, output voltage and output power waveforms by proposed BF-PSO method

By comparing the simulation results of both the methods, before mentioned drawbacks in without MPPT method, overcome by proposed BF-PSO mppt method. The proposed method tracks the maximum output power and maintains the constant voltage level at the output.

VI. CONCLUSION

In this paper, a BF-PSO with open circuit voltage mppt method is used to track the MPP for a PV system. In this open circuit voltage mppt method is used because of it's simplicity and reduced cost. The proposed system was simulated and from the results acquired during the simulation by comparing this proposed method with 'without MPPT', it was confirmed that proposed controller has a number of advantages: 1)It could locate the MPP for different insolations,2) It maintains the constant output voltage.

REFERENCES:

[1] Kashif Ishaque, Zainal Salam, Muhammad Amjad and Saad Mekhilef, "An Improved particle swarm optimization(PSO)- based MPPT for pv with reduced steady state oscillation" ," IEE Trans. Power Electron., vol. 27,no.8,pp.3627-3638, August 2012.

[2] L.Bangyin, D.shanxu, and C.Tao, "Photovoltaic DC-building-module-based BIPV system-concept and design considerations," IEE Trans. Power Electron., vol. 26,no.5,pp.1414-1429, May 2011.

[3] Z.Li, S.Kai,X. Yan, F.Lanlan, and G. Hongjuan, "A modular grid connected photovoltaic generation system based on DC bus," ," IEE Trans. Power Electron., vol. 26,no.2, pp.523-531, Feb 2011.

[4] Y. Bo, L.Wuhua, Z. Yi, and H.Xiangning, "Design and analysis of a grid connected photovoltaic power system," IEEE Trans. Power Electron., vol. 25,no.4,pp.992-1000, April 2010.

[5] A.Dolara, R.Faranda, S.Leva, "Energy comparision of seven MPPT techniques for PV systems" Scientific Research, J.electro magnetic Analysis and Applications,2009,3:152-162

[6] B.N. Alajmi, K.H. Ahmed, S.J. Finny, and B.W. Williams," Fuzzy logic- control approach of modified hill-climbing method for maximum power point in micro grid standalone photovoltaic system, " IEEE Trans. Power Electron., vol. 26,no.4,pp.1022-1030, April 2011.

[7] M.Miyatake, F.Toriumi, T.Endo, and N. Fuzzi, "A Novel maximum power point tracker controlling several converters connected to photovoltaic arrays with particle swarm optimization technique," in Proc. Eur.Conf.Power electron.Appl., 2007, pp.1-10.

[8] Baby Pooja, Satnam Singh DUB, Jang Bahadur singh, PARVEEN Lehana "Solar power optimization using BFO algorithm" ISSN:2277128X volume 3, Issue 12, December 2013.

[9] K.Ishaque,Z. Salam, and H.Taheri, "Simple, fast and accurate two diode model for photovoltaic modules," Solar Energy Mater.Solar cells, vol. 95, pp. 586-594,2011.

[10] S.Chih-Tang, R.N.Noyee, and W. Shockley, "Carrier generation and recombination in P-N junctions and P-N junction characteristics," Proc. IRE, vol. 45, no. 9, pp. 1228-1243,Sep. 1957.

[11] Wael Korani, "Bacteria foraging oriented by particle swarm optimization strategy for PID tuning," University of Cairo,Egypt.