Performance analysis of Firefly Maximum PowerPoint Tracking Technique for PV Grid Connected System

P.Sudheer[1], Dr.Ch.Chengaiah[2]
[1, 2] S.V.University, Tirupati, Andhra Pradesh, India.

Abstract- *Energy is the foremost fundamental concept of a country. Development of the Indian economy in the existing infrastructure is critical. The power sector of the India is one of the biggest expanded section in the globe. Because of the unbroken increment in electricity demand step by step, power sector of India is linking a few critical tasks to maintain the stability between the production and demand of the power with anguish from supply constrictions and scarcities in power. To balance the ratio between production and demand of the power is moving from conventional energy sources to renewable sources.it is not only an substitute for this energy sources, it is an essential. Among all renewable sources solar is a India's most abundant source to increase power production. Tracking and obtaining the maximum power point from the panels either mechanically or electrically is a most crucial research aspect. In electrical tracking, a variety of Maximum power point tracking techniques was developed by the researchers to develop the efficiency in the Photovoltaic systems and it is mainly concentrated in the recent years. This paper centre of attention is on comparison of improved perturb and observe, genetic algorithm with artificial neural network and meta heuristic firefly algorithm for grid connected systems, after modelling and simulating the photovoltaic module and arrays. Finally this paper proves that firefly algorithm is the most efficient compare to the other examined algorithms by using MATLAB/SIMULINK environment.*

Keywords- Maximum power point methods, Perturb &Observe,Genetic algorithm, Artificial neural network, Firefly algorithm, grid connected systems, Modelling and simulation

I. INTRODUCTION

In modern days the demand for production of power increments very quickly and in the other side the accessibility of the conventional energy resources (like coal, petroleum) vitiates considerably which creates a miserable and complicated future in the coming generations. Furthermore Non Renewable energy sources based production of power is having consequence of greenhouse emission. Because of these reasons Renewable Energy based productions has increased multifariously. Among all the non conventional energy tools, Photovoltaic technology is the first-class selection due to its unanimous availability , less cost, ecological friendly, and also less functioning and less maintenance costs [1,2]. The need of Photovoltaic (PV) Generation Systems is increasing in the both applications like stand alone and grid connected systems. So to make the Photovoltaic production competently, an effectual Maximum Power Point Tracking (MPPT) technique is essential to forecast and track the Maximum Power Point at every atmosperhic conditions. To get better performance from the system it should run at the Maximum Power Point [3–6]. A variety of Maximum Power Point Tracking techniques had been offered by many researchers to develop the efficiency of Photovoltaic systems such as Adaptive Perturb& Observe, variable step size Perturb & Observe, modified Incremental Conductance, Fuzzy Logic Controller (FLC), Neural Network (NN) and Particle Swarm Optimization (PSO) based Perturb & Observe etc. These methods consists many variations the characteristics like convergence speed, oscillations around the Maximum Power Point, Complication of the algorithm, cost and requirement of Electronic Equipments [7–10].

II. PHOTOVOLTAIC GRID CONNECTED SYSTEM

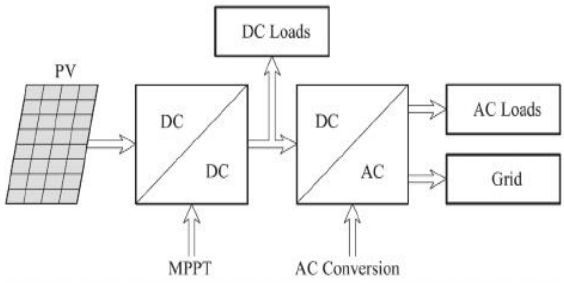

Figure 1. Graphic Diagram of Grid connected Photo Voltaic System

From Fig.1, A grid-connected Photo Voltaic System is an electrical generation system which is connected to the Grid. Grid-connected Photo Voltaic System contains Photo Voltaic arrays, inverters, power conditioning unit and Grid connected equipment. Unlike stand-alone Power Systems, a Grid-Connected system rarely includes an integrated battery ,

it cost is very high. When settings are correct, the Grid-Connected Photo Voltaic System deliveries the extra power, beyond the utilization by the loads, and to the Utility Grid. After converting DC power which comes from DC-DC Converter is utilized to convert into AC power .Finally it is fed to Grid.

III. MODELLING OF PHOTOVOLTAIC MODULE

Photovoltaic module is the basic device which is useful to convert light energy into electrical energy. Modelling of the Photovoltaic module is essential [11], and it requires weather data (Irradiance and Temperature) as the input variables. The output obtained from it ,is current, voltage, power. Conversely, to plot characteristics of I-V or P-V forcibly needs these above said three variables. The changes in these variables directly changes its outputs. The ideal single Diode Model of Photovoltaic cell which is shown in Fig .2 and the practical Diode Model with series and shunt resistance is shown in Fig.3.From these models the modelling equations were noted for modelling purpose which is pointed in below equations.

From the Fig.2 the Model doesn't consider the Internal losses of the current. The connection of the Diode in anti-parallel with the Light Generated Current Source which is the output current I and it is obtained through Kirchhoff's law:

$$I = Iph - Id \quad \text{----------(1)}$$

I_{ph} - photocurrent,
I_d - Diode current which is proportional to the Saturation Current - Io

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

V - voltage imposed on the diode.

$$Vt = K.Tc/q \quad \text{----------(3)}$$

Io - reverse saturation or leakage current of the diode (A),
Vtc - 26 mV at 300 K for silisium cell,
Tc - actual cell temperature (K),
K - Boltzmann constant 1.381 · 10_23 J/K,
Q - Electron charge (1.602 · 10_19 C).
Vt –Thermal voltage
Ns - Number of PV cells connected in series.
A - Ideality factor.

It is necessary to emphasize that the constant A which depends on Photo Voltaic Cell Technology. All the terms by which, Voltage (V) is divided in equation (2) under exponential function are inversely proportional to cell temperature and so, vary with varying conditions. In this work, the term is designed by 'a' and called the thermal voltage (V), the Ideality factor, is considered constant according to technology of the PV cell. The thermal voltage 'a''is presented by equation (4).

a- the modified ideality factor and is considered as a parameter to determine, while A is the diode ideality factor.

$$a = \frac{Ns.A.K.Tc}{q} = Ns.A.Vt \quad \text{----------(4)}$$

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

$$I = Iph - Id - Ip \quad \text{----------(5)}$$

Ip, - Leakage Current in parallel resistor.
According to the mentioned Equation (6), the output current of a module containing cells in series(Ns) and cells in parallel (Np) will be written as below:

$$I=I_{ph}\text{-Io}\left(\exp\left(\frac{V+IRs}{a}\right) - 1\right) - \frac{V+IRs}{Rp} \quad \text{----------(6)}$$

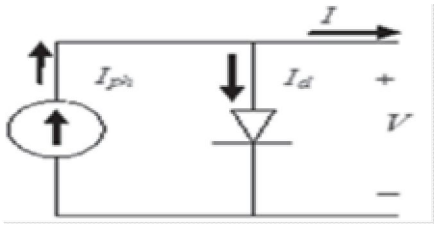

Figure 2. Ideal single diode model

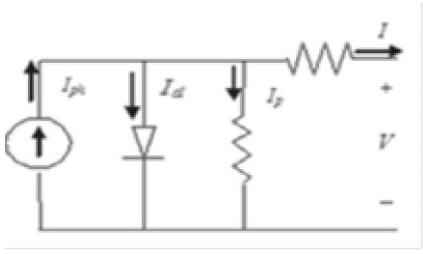

Figure 3.Practical model with Rs and Rp

Table 1. Parameters of SunpowerSPR-305-WHT

Parameters		Values
Open circuit voltage	- Voc	64.2
Short circuit current	- Isc	5.96
Maximum voltage	- Vmp	54.7
Maximum current	- Imp	5.58
Series current	- Rs	0.037998
Shunt current	- Rp	993.51
Saturation current	- Isat	1.175e-08
Photo current	- Iph	5.9602

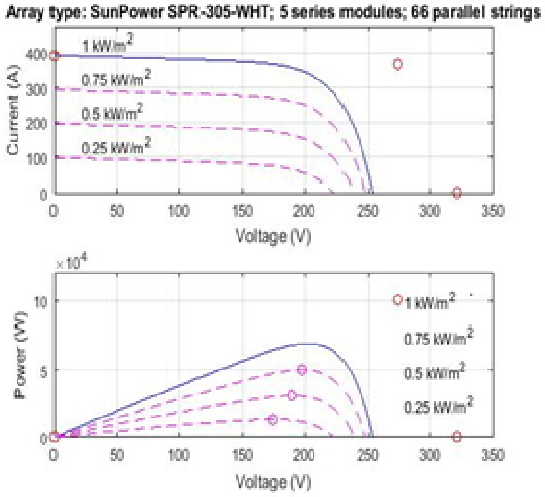

Figure 4. I-V and P-V Characteristics of an Array

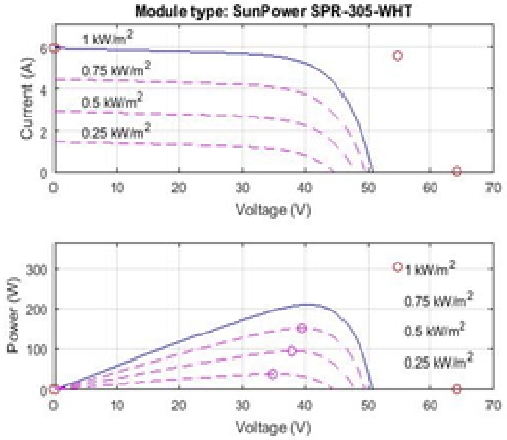

Figure 5. I-V and P-V Characteristics of a Module

IV. MAXIMUM POWER POINT TRACKING METHODS

1. Perturb and Observe Technique

Principle of this method is perturbation of the voltage and the current from the Photo Voltaic in regular Manner , and it compares the fresh power which is measured with the previous power to decide the next perturbation. Perturb and Observe is the technique which works efficiently when the changes of Irradiation is very less. It displays irregular behaviour for briskly changing Irradiations that causes incorrect or slow tracking of the power. This technique is most accepted for Maximum Power Point Tracking [12-19]. Due to its comfort of implementation it is widely accepted and used in many applicatons. After one perturbation the present power is calculated and it is compared with previous power value to determine the change of power .If the cell voltage increases the automatically the Output Power of a cell increases. In this situation the system increases the operating voltage until the Output Power starts to decrease. Once if it happens, the voltage is decreased to regain the maximum Output Power value. This process continues repeatedly until the Maximum Power Point is reached.

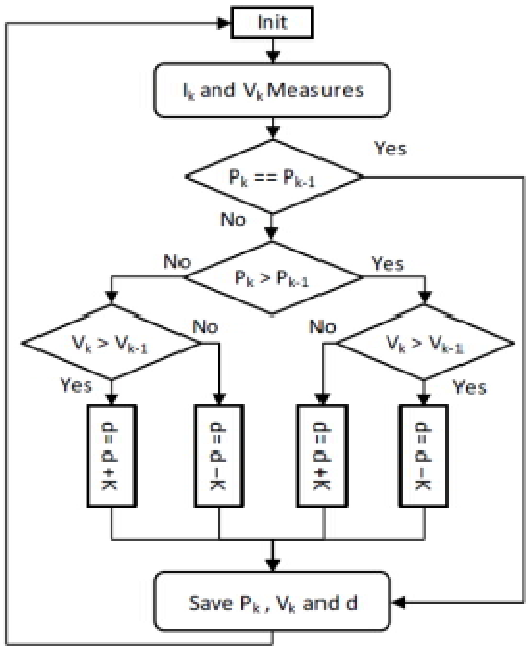

Figure 6. Flow chart of Perturb and Observe method

2. Genetic Algorithm with Artificial Neural Network

Here, the ANN is utilized for improving the performance of GA with aid of updating the mutation parameter. The ANN has only one input, as randomized parameter, and the number of hidden layers. The parameter is given to the input of the networks the appropriate outputs are taken out from the networks. Then output of the ANN is the updated optimal randomized parameter. For developing the mathematical structures, ANNs are fine approach with the capability to learn. Normally Neural network consists of two phases namely, training and testing phases [20]. When the parameter is given as input to the neural network, the most excellent optimal set of parameter is obtained as output in the testing phase [21]. The ANN has different layers like Input layer, Hidden layer and Output layer. Here Back Propagation Algorithm is used to train the Neural Networks.

3. Firefly algorithm

The mentioned Firefly Algorithm (FA) is a meta-heuristic algorithm and it is inspired by the Flashing behaviour of Fireflies. Xin-She Yang [24]. developed this Firefly-Inspired algorithms. For these algorithm following are the three idealized rules given:

1) All the FireFlies are unisex. Irrespective of their sex they are attracted to other FireFlies.
2) The amount of the attractiveness of a FireFly is proportional to its brightness. Among any two flashing fireflies, the less brighter one will move towards the brighter one.More brightness of a FireFly means the distance between two fireflies is less [22]. If there is no brighter FireFly when compared to the other particular firefly then it will move randomly.
3) The brightness of a FireFly was determined by the Objective Function value . The Objective Function which should be Optimized was determined by the brightness of a FireFly. Mathematical equations related to this algorithm are described in detailed in the following sections. The Firefly Algorithm (FA) is effective and easy for implementation than the other Meta-Heuristic Methods [23].The above explained methods are implemented using MATLAB/SIMULINK which is shown in Fig.7.and the results are shown in results section and the analysis of the results also carried out for different irradiation conditions under case studies section and the graphs noted.

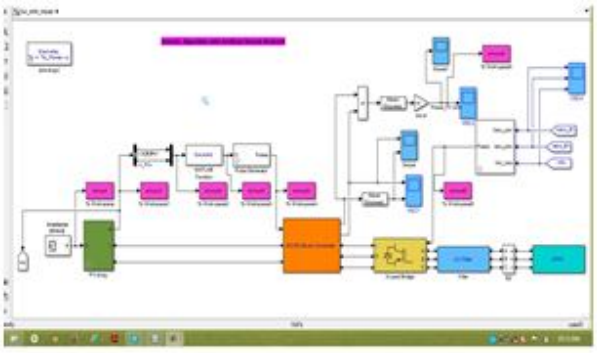

Figure 7. Simulink Model of PhotoVoltaic Grid Connected system

V. RESULTS AND DISCUSSIONS

Perturb and Observe, Genetic algorithm with Artificial neural network ,Firefly algorithm is simulated through MATLAB/SIMULINK environment for grid connected solar system which used Parameters of Sun Power SPR-305-WHT solar panels .Each module consists 96 cells, in series Five Modules are connected which call it as string .Totally 66 strings are connected in parallel . Each module generated approximate power is 305W and the array generated power is 100KW.

Performance analysis

In the below subsection, the Evaluation of performance for the proposed system and its simulation results are depicted and analyzed under change in Irradiation conditions.

The constant solar irradiance is analyzed in the below case study

- Case 1: Analysis of Constant irradiance

Case studies:

Here the MaximumPowerPoint was controlled by the proposed Firefly Algorithm. Converter circuit uses the predicted voltage and current for controlling purpose to get the optimal sinusoidal waveform. This system was simulated to acquire the knowledge in operation of the PhotoVoltaic-Grid connected system. Here ,the Proposed method is compared with the existing method such as P&O technique, GA-ANN method. Initially the panel irradiance, power, voltage and currents are analyzed in the normal conditions and illustrated in the Fig. 8 (a), (b) ,(c)and (d)respectively.

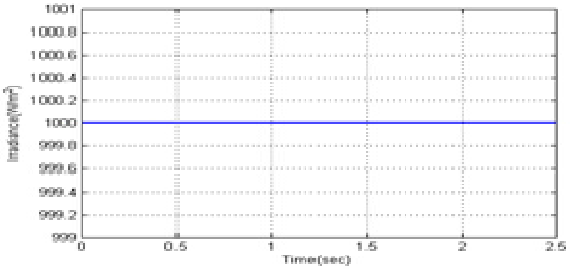

Figure a

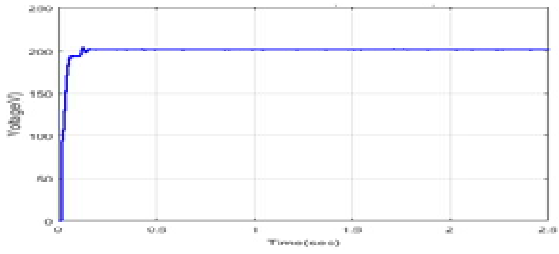

Figure b

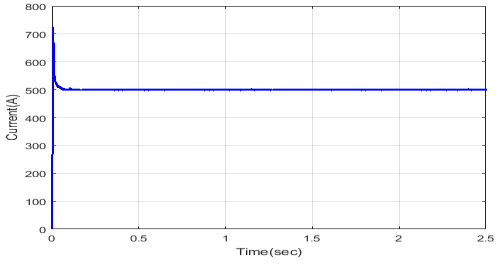

Figure c

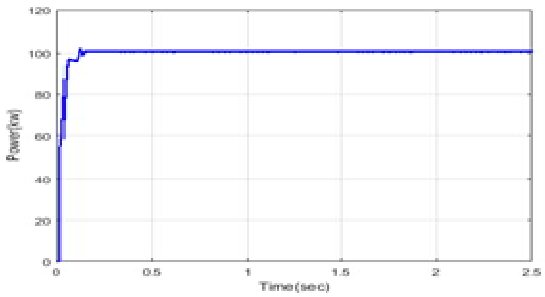

Figure d

Figure 8. Analysis of Performance :(a) irradiance (b) Panel Voltage (c) Current and (d) Power using MPPT technique

Fig. 8 shows management of Power for the basic Model under the constant solar irradiance which can be observed from Figure 8 (a) and (b) .The Maximum Tracking of the power by using proposed technique is analyzed at time t= 0 to 2.5 sec the maximum power of the proposed model is illustrated at the constant irradiance. The Maximum power point tracking is analyzed under various PV irradiance and the different time instants. These performances are analyzed in the different cases such as, Case 1 and Case 2 respectively. The Outputs of the Proposed method are analyzed and compared with Perturb& Observe technique and GA-ANN. Similarly,other methods are also applied and evaluted .The obtained voltage, power and current values are noted for the system performances. The comparison analysis of proposed and existing methods are illustrated in the Fig.9 .

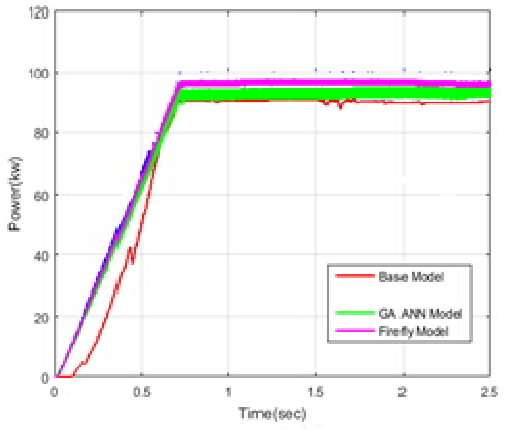

Figure 9. Comparison analysis of power using various methods

From the above illustrations, the performance of maximum power tracking is analyzed by using FA and different techniques P&O, and GA-ANN. Here the maximized power of PV is analyzed. The perturb and observe method achieved maximum 85kw power with oscillations.GA-ANN reached approximately 90kw of power with less oscillations compared to conventional method. But the proposed firefly method achieved maximum of 98 kw of power with minimal of oscillations.

Case studies: 2

In the section, the most probable situations at various irradiance conditions the system was analyzed and the obtained values of current, voltage, and the power are noted .Initially the PhotoVoltaic voltage, current and irradiance are analyzed in the normal conditions. As observed from the Figure.10.the solar irradiance is varied that is decreased from its normal irradiance and again it is increased and finally reached to normal irradiance. From the above illustrations, the performances of power graph is illustrated and compared with the existing method in different cases. Here the Maximum Power can be tracked by using the proposed Maximum Power PointTracking controller and the existing controller such as P&O, and GA-ANN technique. The power is almost achieved to the maximum level under all the cases. In the Case 1, the time instant t=0 to 2.5 sec, the power is tracked under the PV irradiance varying condition. With P&O technique, the power curve of PV is initially increased 100 at time instant t=0.001. From t=1sec, the output curve starts to decrease slowly and reaches the regulated power (75) after t=0.02sec. After that, the curve is increased at the time instant t= 2.1sec. While using the ANN technique, initially the curve reaches the power at a high rate at t=0.01 sec. In our proposed technique, the output power decreases gradually from the time instant t=0.75 to 2 sec and reaches its maximum power of 75 at t=1 to 1.8 sec. After reaching the maximum power, the curve goes constantly.

VI. CONCLUSION

In this paper, FA technique was used for tracking the maximum power of PV system. The proposed MPPT controller design has inputs panel voltage and current. The output of proposed method was analysed and evaluated 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 was compared with the existing methods, such as, P&O, GA-ANN methods. Moreover it is proven that the Proposed Controller is robust for the different cases which is having different input solar irradiance conditions. The deviation rate of tracking performances of the Proposed Method was compared with the remaining used methods. The maximum power of the Proposed Method and existing techniques are Tracked and analyzed. The simulation results show that the proposed controller overcomes the disturbances in the power curve with maximum power attained as 98kw which is the maximum

compared to the other methods. And it also taken less time to track the maximum power.

REFERENCES

[1] Amelia MT, Mosleh pourb S, Shamloa M. Economical load distribution in power networks that include hybrid solar power plants. Electr Power Syst Res 2008;78(7):1147–52.

[2] Reisi A R, Moradi MH, Jamasb S. Classification and comparison of maximum power point tracking techniques for photo voltaic system: a review. Renew Sustain EnergyRev2013;19:433–43.

[3] Enrique JM, Andujar JM, Bohorquez MA. Areliable, fast, and low cost max imum power point tracker for photovoltaic applications. Sol Energy2010; 84(1):79–89.

[4] Lim YH, Hamill DC. Simple maximum power point tracker for photovoltaic arrays. ElectronLett 2000; 36(11):997–9.

[5] Salas V, Olias E, Barrado A, Lazaro A. Review of the maximum power point trackingalgorithmforstand-alonephotovoltaicsystem.SolEnergyMaterSol Cells 2006;90(11):1555–78.

[6] Chihchiang H, Chihming S. Study of maximum power tracking techniques and control of DC/DC converter or photovoltaic power system. In:Proceedingsof the IEEEconferenceon PESCpower electronics specialists; 1998.p.86–93.

[7] De CesareG, Caputo D,Nascetti A. Maximum power point tracker for photo- voltaicsystems with resistive like load. SolEnergy2006;80(8):982–8.

[8] Ramprava R, Mathur BL. Intelligent controller based maximum power point tracking for solar PVsystem .IntJComputAppl2011;12(10):37–41.

[9] Chowdhury S, Saha H. Maximum power point tracking of partially shaded solar photovoltaicarrays. Sol Energy MaterSolCells2010;94(1):1441–7.

[10] IyasereE, TatliciogluE, Dawson DM. Back-stepping PWM control for max imum power tracking in photo voltaic array systems. In : Proceedings of the conference onAmericancontrol;2010.p.3561–3565.

[11] 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.

[12] Wasynczuk O. Dynamic behavior of a class of photovoltaic power systems. IEEE Transactions on PowerApplications System 1983; 102(9): 3031–7.

[13] Hua C, Lin JR. DSP-based controller application in battery storage of photovoltaic system. IEEE IECON 22nd Int.Conf. Ind. Electron., Contr. Instrum. 1996; 1705–1710.

[14] Slonim MA, Rahovich LM. Maximum power point regulator for 4 kW solar cell array connected through invertor to the AC grid. Proc. 31st Intersociety Energy Conver. Eng. Conf, 1996; 1669–1672.

[15] Al-Amoudi A, Zhang L. Optimal control of a grid-connected PV system for maximum power point tracking and unity power factor. Proc. Seventh Int. Conf. Power Electron. Variable Speed Drives 1998; 80–85.

[16] Hua C, Lin J, Shen C. Implementation of a DSP-controlled photovoltaic system with peak power tracking. IEEE Transactions on Industrial Electronics 1998; 45(1): 99–107.

[17] Kasa N, Iida T, Iwamoto H. Maximum power point tracking with capacitor identifier for photovoltaic power system. Proc. Eighth Int. Conf. Power Electron. Variable Speed Drives 2000; 130–135.

[18] Bianconi E, Calvente J, Giral R,, Mamarelis E, Petrone G, Ramos-Paja CA, et al. Perturb and observe MPPT algorithm with a current controller based on the sliding mode. International Journal of Electrical Power & Energy Systems; 12013346–2013356; 44.

[19] Abdelsalam AK, Massoud AM, Ahmed S, Enjeti PN. High-performance adaptive perturb and observe MPPT technique for photovoltaic-based microgrids. IEEE Transactions on Power Electronics 2011; 26(4).

[20] Bretas AS, Phadke AG, "Artificial neural networks in power system restoration", IEEE Transactions on Power Delivery, Vol. 18, No.4, pp. 1181-6, 2003.

[21] Eisa Bashier M Tayeb, "Faults Detection in Power Systems Using Artificial Neural Network", American

Journal of Engineering Research (AJER), Vol. 02, No. 06, pp-69-75, 2013

[22] Iztok Fister, Matjaz Perc, Salahuddin M. Kamal and Iztok Fister, "A review of chaos-based firefly algorithms: Perspectives and research challenges", Applied Mathematics and Computation, Vol. 252, pp. 155–165, 2015

[23] P. Sarmila Devi and S. Bharath, "Firefly Algorithm Based Approach for Stability Enhancement in Interconnected Power System Using PSS", International Journal of Emerging Technology and Advanced Engineering, Certified Journal, Vol. 5, No. 4, April 2015

[24] Nadhir K, Chabane D, Tarek B, "Distributed generation location and size determination to reduce power losses of a distribution feeder by Firefly Algorithm", International Journal of Adv. Sci. Technologies, pp. 61-72, 2013