MAT JOURNALS

Journal of Controller and Converters
Volume 2 Issue 2

Review of Maximum Power Point Tracking for Photovoltaic Systems

Sonali Prabhakar Tonde[1], Prajakta Hanuman Dhekale[2], Manisha Sugreev Bade[3], Prof. Anil Bodhe[4]

[1, 2, 3] Student, Electrical Engineering Department, S.B.Patil College of Engineering Vangali, Indapur, Maharashtra, India.

[4] Assistant Professor, Electrical Engineering Department, S.B.Patil College Of Engineering Vangali, Indapur, Maharashtra, India.

sonali.tonde1234@gmail.com, prajaktadhekale03@gmail.com, manishabade26@gmail.com, anilindore1987@gmail.com

Abstract

The demand of electrical energy is increasing with industrial development and the rate of generation is unable to keep pace with increasing demand. The conventional energy sources are limited so the obvious choice of clean, free source of energy which provides safety for the development is solar energy. But PV system has certain disadvantages like: low conversion efficiency, high cost of installation hence we preferred MPPT for extracting the maximum power output from Photovoltaic system. The output characteristic of photovoltaic array is non-linear. The output power depends on temperature & irradiance. The common maximum power point tracking (MPPT) techniques are Hill Climbing (HC), Incremental Conductance (IC), Perturbation and Observation (P&O) but all these techniques have certain drawbacks. So these drawbacks are minimized by using intelligent optimization techniques such as, Particle Swarm Optimization (PSO), Artificial Neural Network (ANN), Artificial Bee Colony (ABC), Ant Colony Optimization (ACO), Genetic Algorithm (GA), and Fuzzy Logic Control (FLC). All these techniques are used for extracting maximum power from Photovoltaic (PV) System.

Keywords: *Photovoltaic (PV) System, Maximum Power Point Tracker (MPPT), Intelligent Optimization Technique, Particle Swarm Optimization (PSO), Fuzzy Logic Control (FLC), Artificial Neural Network (ANN), Artificial Bee Colony (ABC), Genetic Algorithm (GA), Ant Colony Optimization (ACO).*

INTRODUCTION

Solar energy is important and pollution free renewable energy source. It is maintenance free, ecological and everlasting. PV sources shows nonlinear V-I characteristics. The power is generated from PV module and generated power depends upon density of solar radiation and temperature [3]. PV module produces the maximum output power at Maximum Power Point (MPP) which is corresponding to the actual values of solar irradiation, cells module temperature. Maximum Power Point (MPP) is a point on the I-V characteristic. Maximum Power Point (MPP) is also a point on P-V characteristic of solar panel. Controlling MPPT is essential in a PV system to reduce the cost of produced electrical energy [11]. The power output depends on the nature of the connected load. So direct load connections to PV systems gives poor overall efficiency. As solar panels are expensive so to minimize cost of their life cycle direct connected PV systems are replaced by PV systems having maximum power point (MPP) tracker [7].

Various conventional MPPT techniques are discussed in many review papers. These conventional techniques ripple correlation control approaches, Perturb and

Observe, Incremental Conductance, open circuit voltage, short circuit current. All these methods are applicable under uniform radiance condition. Various intelligence based MPPT techniques are discussed in this paper. The techniques discussed are Particle Swarm optimization (PSO) algorithm, Fuzzy Logic Control (FLC), Ant Colony Optimization (ACO), Artificial Neural Network (ANN), Genetic Algorithm (GA) [3].

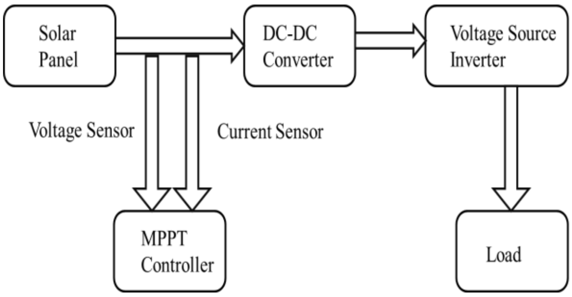

Fig1.: *Block diagram of DC-DC Converter interfacing with load*

Problem Statement

Double diode model

To evaluate performance of solar photovoltaic cells two models are used. These models are single diode model and double diode model. In single diode model five parameters are unknown while in double diode model seven parameters are unknown. The double diode model is more accurate so it is preferred in this paper.

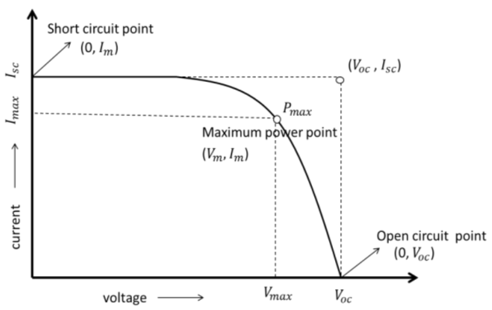

Fig2. *I–V characteristics curve of a PV cell.*

These models exhibit voltage and current data as output. Output data provide the I–V characteristic curve as shown in Fig. 1 [3].

The figure given below shows the double diode model in which I_{pv} is photovoltaic current, I output current, I_{d1} current through diode 1, I_{d2}current through diode 2 and V is voltage across load.

The output current can be derived by using Kirchhoff's Current Law (KCL). So, now by applying KCL,

The output current of the cell is given by,

$I = I_{pv} - I_{d1} - I_{d2} - I_{sh}$

$$I = I_{pv} - I_{d1} - I_{d2} - \left(\frac{V+IR_s}{R_{sh}}\right) \quad (1)$$

Where,

R_s= Resistance offered to the current flow due to

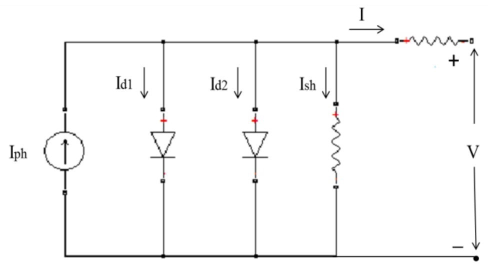

Fig3. *Two-diode model of the PV cell*

Ohmic contact

R_{sh} = Resistance due to impurity concentrations along with junction depth.

Here, the current through the diode d_1 in terms of saturation current (I_{s1}), ideality factor (a_1),

Thermal voltage (V_{T1}) is given as,

$$I_{d1} = I_{s1}\left[exp\left(\frac{V+IR_s}{a_1 V_{T1}}\right) - 1\right] \quad (2)$$

And the current through the diode d_2 in terms of saturation current (I_{s2}), ideality factor (a_2),

Thermal voltage (V_{T2}) is given as,

$$I_{d2} = I_{s2}\left[exp\left(\frac{V+IR_s}{a_2 V_{T2}}\right) - 1\right] \quad (3)$$

Let's put values of diode currents in equation (1).Now equation 1 becomes,

$$I = I_{pv} - I_{s1}\left[exp\left(\frac{V+IR_s}{a_1 V_{T1}}\right) - 1\right] - I_{s2}\left[exp\left(\frac{V+IR_s}{a_2 V_{T2}}\right) - 1\right] - \left(\frac{V+IR_s}{R_{sh}}\right) \quad (4)$$

In this equation thermal voltage V_T is,

$$V_T=\frac{\alpha KT}{q} \qquad (5)$$

Where,
q= Electron charge (1.6x10^ (-19) Coulombs)
K= Boltzmann constant (1.38x10^ (-23) Nm/K)
T= PV Module temperature in Kelvin

The photo generated current in terms of photovoltaic current at standard test condition ($I_{pv_{STC}}$) is given as,

$$I_{pv}=\left(I_{pv_{STC}}+K_I\Delta T\right)\frac{G}{G_{STC}} \qquad (6)$$

Where,
K_I= current temperature coefficient
ΔT= temperature difference between the module temperature and the STC temperature
G= irradiance in (kW/m2)
G_{STC}= irradiance at standard test condition in (kW/m2)

The saturation current is given as,

$$I_s=\frac{I_{sc_{STC}}+K_I\Delta T}{exp\left[\frac{(V_{OC}+K_V\Delta T)}{V_T}\right]-1} \qquad (7)$$

The output current in terms of number of PV module connected in series (N_s) and number of PV module connected parallel (N_p) is given as [5],

$$I=N_p\left\{I_{pv}-I_{s1}\left[exp\left(\frac{V+IR_s\left(\frac{N_s}{N_p}\right)}{N_sV_{T1}}\right)-1\right]-I_{s2}\left[exp\left(\frac{V+IR_s\left(\frac{N_s}{N_p}\right)}{N_sV_{T2}}\right)-1\right]\right\}-\left\{\left(\frac{V+IR_s\left(\frac{N_s}{N_p}\right)}{R_{sh}\left(\frac{N_s}{N_p}\right)}\right)\right\} \qquad (8)$$

The resistance due to impurity concentrations along with junction depth R_p is given by the below equation,

$$R_p=\frac{V_{mp}(V_{mp}+I_mR_s)}{[V_{mp}\{I_{pv}-I_{d1}-I_{d2}\}-P_{max,E}]} \qquad (9)$$

Where,
V_{mp}= Voltage at maximum power.
I_m= Current at maximum power.

The ideality factor of diode 2 (α_2) in given as,

$$\alpha_2=\frac{qV_{oc}}{N_sKTln\left\{\frac{I_{pv}-I_{s1}\left[exp\left(\frac{qV_{OC}}{N_sKT}\right)-1\right]+1}{I_{s2}}\right\}} \qquad (10)$$

The open circuit voltage (V_{oc}) is given by,

$$V_{oc}=\frac{\alpha KT}{q}\,ln\frac{I_{pv}}{I_s} \qquad (11)$$

The expression for initial duty cycle of PSO algorithm is:

$$d=\frac{1}{\left(1+\sqrt{\frac{R_{\text{in}}}{R_o}}\right)} \qquad (12)$$

Where,
R_{in}= Internal resistance of PV module
R_o= Output load resistance

$$R_{\text{in}}=\frac{V_{mp}}{I_{mp}} \qquad (13)$$

Where,
V_{mp}= Voltage at maximum power point
I_{mp}= Current at maximum power point

$$V_{mp}=K_1V_{oc} \qquad (14)$$

$$I_{mp}=K_2I_{sc} \qquad (15)$$

Where,
K_1 and K_2 are the constant of proportionalities. K_1 and K_2 change with the change in irradiation and temperature.

The equation corresponding to K_1 and K_2 can be derived for a particular panel:

$$K_1=\frac{V_{mpn}}{V_{ocn}}\left[1+\left(\alpha ln\frac{G}{G_n}\right)+\beta(T-T_n)\right] \qquad (16)$$

$$K_2=\frac{I_{mpn}}{I_{scn}}\left[1+\left(\gamma ln\frac{G}{G_n}\right)\right] \qquad (17)$$

The values of α, β and γ are 0.03, 0.004, and 0.014 respectively [5].

Intelligent Optimisation Techniques:

1. Particle Swarm Optimization:

Particle Swarm Optimization was introduced by Kennedy and Eberhart in 1995. This algorithm deals with interactive particles which share information gathered in search space. Each particle is tracking the best solution based on information gathered in search space. The velocity and position of particle is given as [6]. Particle swarm optimization (PSO) algorithm is used in both non-uniform and uniform density of solar radiation. It is advantageous if used in multiple peak curve optimization problem. In MPPT location of maximum power point can be tracked quickly and accurately by using Particle swarm optimization (PSO) technique [2].

$$V_i(K+1)=wV_i(K)+C_1r_1\left(pbest_i(K)-X_i\,(K)\right)+C_2r_2\left(gbest_i(K)-X_i\,(K)\right)$$
$$X_i(K+1)=X_i\,(K)+V_i(K+1)$$

Where,

$V_i(K)$: Current velocity of the i^{th} particle.
$X_i(K)$: Current position of the i^{th} particle.
k: Kth current iteration number, $1\leq k\leq n$.
n: Maximum iteration number.
i: i^{th} particle of swarm, $1\leq i\leq N$.

Global best position is chosen from the best solution of each particle.

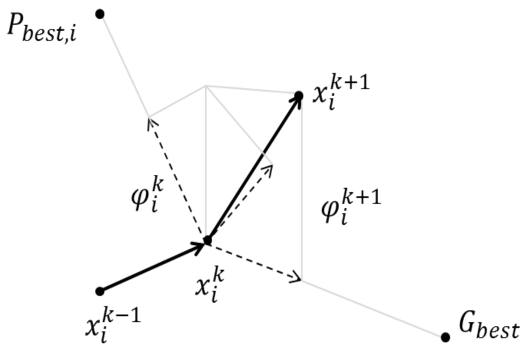

***Fig4.** Movement of a PSO agent in search space.*

Fuzzy Logic Control

Fuzzy logic technique is used to track the MPP in PV systems. Improved Performance, low cost of micro controllers has made Fuzzy logic technique more accessible. Fuzzy logic controllers have three stages fuzzification, fuzzy inference mechanisms and defuzzification. This method has ability to handle non-linearity. This method is accurate in changing climatic conditions [9].

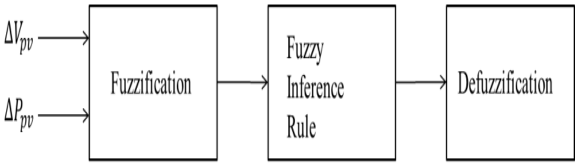

***Fig5.** Fuzzy Logic Control Technique.*

Inputs are change in power and voltage for MPPT controller with fuzzy logic. At sampling instants k, error (E) and the change of the error (dE) are calculated:

$$E(K)=\frac{dp}{dv}=\frac{P(k)-P(k-1)}{V(k)-V(k-1)}$$

$$dE(k)=E(k)-E(k-1)$$

Where,

P (k) = Power delivered by PV module.
V (k) = Terminal voltage of the module.
E (k) = Value of the error.

Artificial Neural Network:

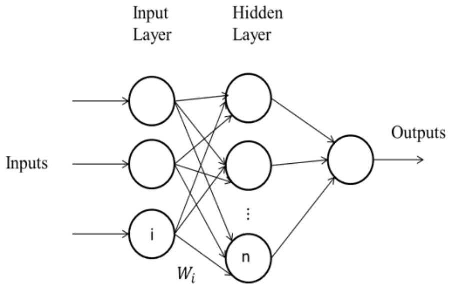

Fig6. *Example of neural network.*

Artificial neural network is used in non-uniform irradiance condition in MPPT of PV array system. Neural networks mainly have three layers. These layers are input layer, hidden layer and output layer. The input variables are short circuit current (I_{sc}), open circuit voltage (V_{oc}), atmospheric data. One or more reference signals are extracted from system output. Hidden layer is used to obtain maximum power point [9].

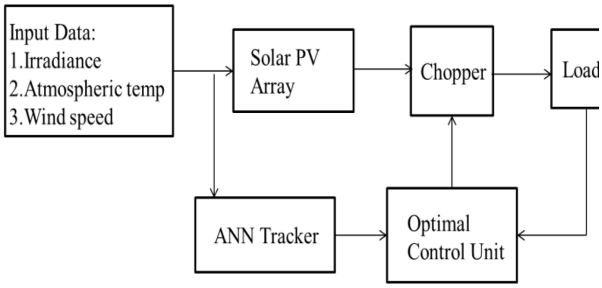

Fig7. *MPPT controller using ANN algorithm.*

Artificial Bee Colony

Artificial Bee Colony algorithm imitates behavior shown by bee colonies and from its collective intelligence comes forth to maximize nectar amount. Potential solution vector of problem is treated as position of nectar source. Quality of solution is obtained from nectar amount of food source. Employed bee, scout bee, onlooker bee are functional groups in bee colony. Half of colony consists of onlookers. Another half of colony consists of employed bee. An employed bee perpetually goes to previously known nectar source. Then select new food source by using visual information from its neighborhood. Bee forgets old position and memorizes new position when amount of nectar of previous position is less than new position. Best food source position at present found out by the employed bee is followed by onlooker bee which is waiting at hive. When the search process ceases, employed bee becomes a scout and starts to search for a new position [10].

Genetic Algorithm (GA)

Genetic Algorithm (GA) is an optimization technique. Genetic Algorithm (GA) resembles to natural genetics. In Genetic Algorithm (GA) technique, "survival of the fittest" principle is used to determine optimal set of parameters. Genetic Algorithm (GA) has number of candidate solutions and these solutions are called as a population. Genetic Algorithm (GA) repeatedly modifies them. GA chooses parents from current population at each step. Children are produced for the next generation by using parents. Chromosomes are candidate solutions. Chromosomes are presented as strings of fixed length. Goodness of each member of population is reflected as an objective function [1].

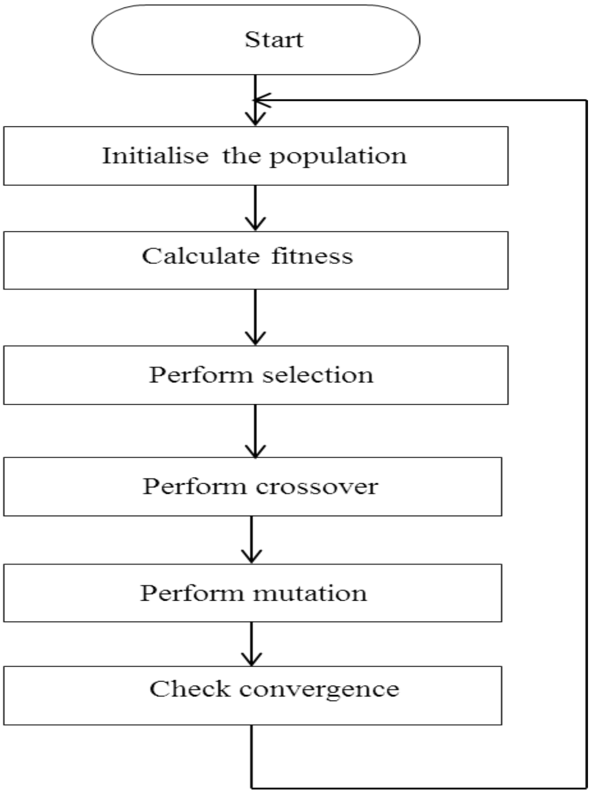

Fig8. *Basic steps of GA*

Ant Colony Optimization
Global optimal solution of non-linear problem is found out by Ant Colony Optimization (ACO). Ant Colony Optimization (ACO) is a probabilistic algorithm. Ant Colony Optimization imitates foraging behavior of ants to obtain optimized path in a graph. Positive feedback phenomenon is formed by collective behavior of huge number of ants. Path searched by the ants is random initially. Pheromone is laid down by ants for other ants to follow. Density of pheromone is higher on the path when large number of ants travels the same path.

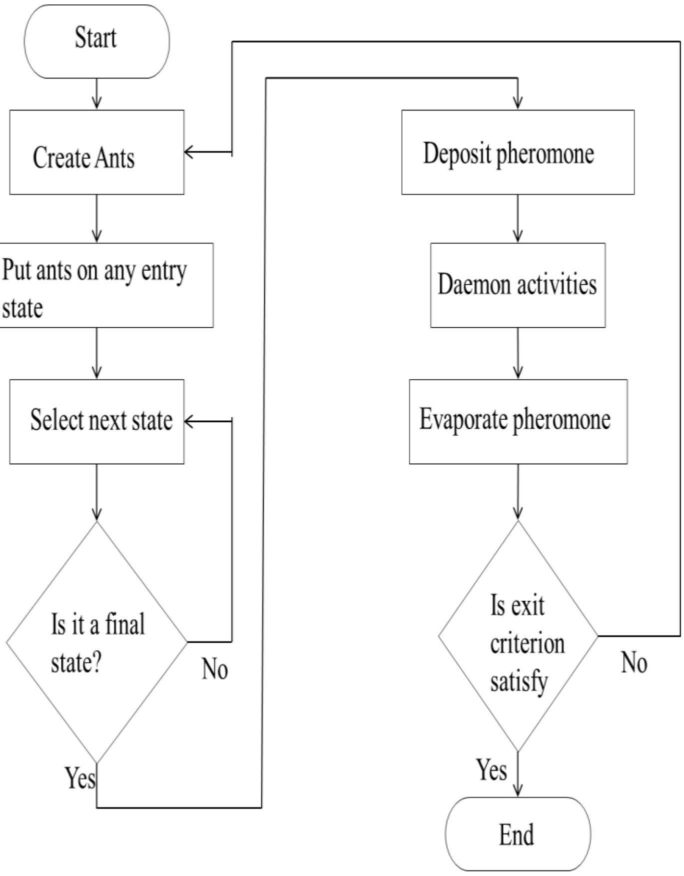

Fig9. *Flowchart of the proposed ACO-based MPPT algorithm for PV systems.*

So, the succeeding ants will travel the path where density of pheromone is more. At last, more number of the ants follows the path till individual ant search shortest path by exchange of information [8].

REFERENCES

1. Yousra Shaiek, Mouna Ben Smida, Anis Sakly, Mohamed Faouzi Mimouni, ”Comparison between conventional methods and GA approach for maximum power point tracking of shaded solar PV generators”,Elsevier,4 January 2013.
2. Wang Yunliang, Bian Nan, ”Research of MPPT Control Method Based on PSO Algorithm”, 2015 4th International Conference on Computer Science and Network Technology (ICCSNT 2015)
3. T. Logeswaran, A. Senthil Kumar,” A Review of Maximum Power Point Tracking Algorithms for Photovoltaic Systems under Uniform and Non-Uniform irradiances”, 4th International Conference on Advances in Energy Research 2013, ICAER 2013,pp 228 – 235.
4. Sangram Bana, R.P. Saini,” A mathematical modeling framework to evaluate the performance of single diode and double diode based SPV systems”, pp. 171–187
5. Rajasekar, Vysakh M, Harshal Vilas Thakur,S Mohammed Azharuddin, Muralidhar K, Don Paul,Basil Jacob, Karthik Balasubramanian, T Sudhakar Babu,” Application of modified particle swarm optimization for maximum power point tracking under partial shading condition”, The 6th International Conference on Applied Energy – ICAE2014,pp. 2633 – 2639
6. Pallavi T. Sawant ,C. L. Bhattar,” Optimization of PV System using Particle Swarm Algorithm under

Dynamic Weather Conditions”, 2016 IEEE 6th International Conference on Advanced Computing.
7. Masafumi Miyatake, Mummadi Veerachary, ”maximum power point tracking of multiple photovoltaic arrays: a pso approach”,IEEE transactions on aerospace and electronic systems vol. 47, no. 1 January 2011.
8. Lian Lian Jianga, Douglas L. Maskell, Jagdish C. Patra,”A novel ant colony optimization-based maximum power point tracking for photovoltaic systems under partially shaded conditions”.Elsevier,2012.
9. Leopoldo Gil-Antonio, Martha Belem Saldivar-M´arquez, Otniel Portillo-Rodriguez,” Maximum power point tracking techniques in photovoltaic systems: A brief review”, 2016 13th International Conference on Power Electronics (CIEP).
10. Kinattingal Sundareswaran, Peddapati Sankar, P. S. R. Nayak, Sishaj P. Simon, and Sankaran Palani, ”Enhanced Energy Output From a PV System Under Partial Shaded Conditions Through Artificial Bee Colony”,2014 IEEE.
11. Jemaa AYMEN, Zarrad ONS,”Maximum Power Point Tracking of Photovoltaic Modules Comparison of Fuzzy Logic and Artificial Network Controllers Performances”.