

An Improved MPPT of SPV System using PSO

Dipasri Saha

Assistant Professor, Department of Electronics and Communication Engineering, GNIT, Kolkata, India

ABSTRACT: Due to increasing energy demand, depletion of fossil fuel resources, requirement of pollution reduction solar energy is becoming an important alternative solution as non-conventional energy source observing its positive impact on society and nature. The photovoltaic module is an unstable source of energy as the maximum power output from solar module depends on temperature and irradiation for all instances imparting non-linearity in output characteristic. This dependency necessitates the tracking of Maximum Power Point. A comparative study of MPPT method using Particle Swarm Optimization applied to two different Swarms is presented in this paper. “Simulink” facility is used to build MPPT controller for stand-alone Solar Power Generation System.

KEYWORDS: Particle Swarm Optimization (PSO), Maximum Power Point Tracking (MPPT), Solar cell, MATLAB, Simulink.

I. INTRODUCTION

The rapid depletion of conventional energy resources necessitates the exploration of renewable energy sources which are unpolluted, free and abundant in nature. One of the important renewable energy resources is solar energy [1] & [2]. Solar finds applications in lighting, water pumping, hybrid systems, and air conditioning, vehicle, military and space applications [3] & [4]. Solar cell is a device which converts solar energy into electric energy. Due to non-linear characteristic solar cell delivers maximum power output at an optimum operating point which varies with solar irradiation, temperature [5]. This unstable nature of Maximum Power Point (MPP) has increased research interest to develop various Maximum Power Point Tracking techniques [6]–[8]. These techniques vary in complexity, accuracy and speed. There are direct and indirect methods of MPPT [9] & [10]. VMPPT & CMPPT are the MPPT methods which calculate MPP using open circuit voltage (V_{oc}) and short circuit current (I_{sc}) respectively [11]. Look-up Table method is difficult to store and record all operating condition due to nonlinear and unstable nature of solar characteristics [12] & [13]. In Perturb & Observe (P&O) method MPP is obtained by perturbation and observation of solar cell output (voltage, current or power). This is a very simple and popular MPPT technique [14]–[16]. Many researchers report that the Incremental Conductance (INC) algorithm offers better performance than the P&O algorithm during rapidly changing weather conditions exhibiting lower confusion [17] & [18]. Whereas Fuzzy is relatively simple to design as fuzzy do not require any information about the exact model [19] & [20]. Using Artificial Neural Network (ANN) the tracking algorithm changes the duty ratio or voltage of the converter so that the PV array voltage equals the voltage corresponding to the MPP at that condition. The controller takes error and change of error signals as input to generate the DC-DC converter duty-cycle [21]–[23]. An alternative approach is Evolutionary Algorithm (EA) which can handle non-linear objective function [24] & [25]. Among EA techniques Particle Swarm Optimization (PSO) method is advantageous as it reduced the steady state oscillation practically zero once MPP is located and the algorithm is simple, can be computed very rapidly and can be implemented using low cost microcontroller [26].

To capitalize that particular advantage, this paper proposes an improvement in MPPT method based on PSO algorithm applied to two different swarms- solar cell output voltage and duty-cycle. The modeling of the PV module is discussed in section 2. Section 3 describes the overview of the PSO and how it is applied to track the MPP. In next section experimental result is discussed and the conclusion is made in the last section.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Special Issue 13, October 2016

II. CHARACTERISTICS OF SOLAR CELL

The Solar cell can be considered as a two terminal device which conducts like a diode in the dark and generates a photo voltage when exposed to Sunlight. When the cell is open circuited, this current is shunted internally by the intrinsic p-n junction diode and when it is short circuited, this current flows in the external circuit. Solar module is designed in MATLAB using the different characteristics equations 1-9 [27]. P-V characteristic obtained by MATLAB SIMULINK MODEL (Fig.3) is depicted in Fig.2.

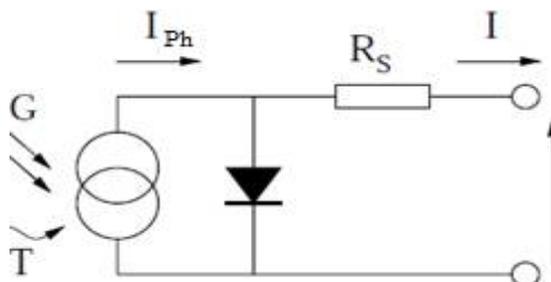


Fig. 1 1-Diode Solar Cell Model
Solar Cell Obtained in MATLAB

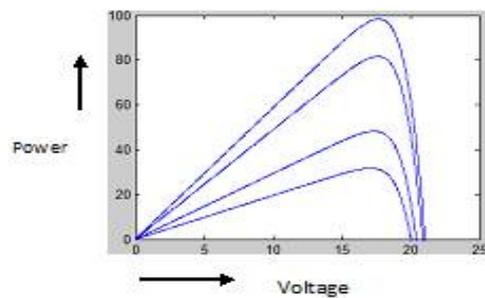


Fig. 2 PV Characteristics of

$$I_d = I_o (e^{q(V+IR_s)/nKT}) - 1 \quad [1]$$

$$I = I_L - I_o (e^{q(V+IR_s)/nKT}) \quad [2]$$

$$I_L = I_L(T_1)(1 + K_o (T - T_1)) \quad [3]$$

$$I_L(T_1) = G * I_{sc}(T_1,nom)/G_{(nom)} \quad [4]$$

$$K_o = (I_{sc}(T_2) - I_{sc}(T_1))/(T_2 - T_1) \quad [5]$$

$$I_o = I_o(T_1) * (T/T_1)^{3/n} * e^{-qV_g/nK*(\frac{3}{T}-1/T_1)} \quad [6]$$

$$I_o(T_1) = I_{sc}(T_1)/e^{qV_{oc}(T_1)/nKT_1} - 1 \quad [7]$$

$$R_s = -dV/dI_{V_{oc}} - 1/X_v \quad [8]$$

$$X_v = I_o(T_1) * \frac{q}{nKT_1} * e^{qV_{oc}(T_1)/nKT_1} \quad [9]$$

I_L =Photo generated current(A)

I_o =saturation current(A)

n =Ideality factor

G =Irradiance

R_s =Series resistance (Ω)

q =electron charge= 1.6×10^{-19} (in coulombs)

k =Boltzmann's constant= 1.38×10^{-23} (in Joules/ Kelvin)

T_1 = STC -Standard Test Condition (25°C)

T_2 =Operating Temperature (varies upto75°C)

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Special Issue 13, October 2016

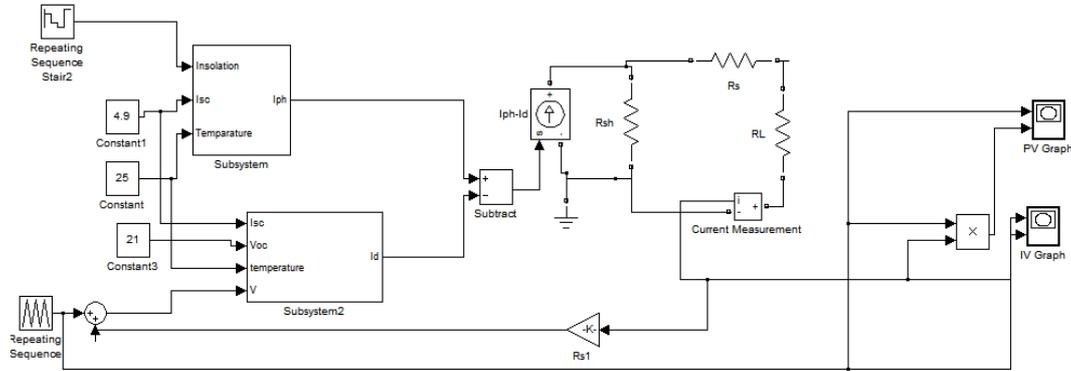


Fig. 3 Simulink Model of PV array

III. MPP TRACKING METHOD BASED ON PSO

A. OVERVIEW OF PSO ALGORITHM

In PSO, each particle is initialized within the solution space in a random way, in which particle's position means results of optimized questions, and particle's speed represents particle's moving direction. The optimized particle in the swarm delivers information to other particles, and all particles follow the optimized particle in the solution space, searching with the optimized direction of fitness function. And the whole searching process follows the current optimal solution to achieve the goal.

Swarm is calculated using eqn.10.

$$Swarm = lb + (ub - lb) \cdot rand(SwarmSize, Dim) \quad [10]$$

lb -> lower bound, ub -> upper bound, Dim->Dimension

Position and Velocity attributes of particle (Swarm) are described by eqn. 11,12 respectively.

$$X_i^{t+1} = X_i^t + V_i^{t+1} \quad [11]$$

$$V_i^{t+1} = \omega \cdot V_i^t + c_1 \cdot r_1 \{P_{best_i} - X_i^t\} + c_2 \cdot r_2 \{G_{best} - X_i^t\} \quad [12]$$

Where t is no. of iteration, ω is the inertia weight, c_1 and c_2 are the acceleration coefficients. P_{best_i} is the personal best position of particle i, and G_{best} is the best position of the particles in the entire population.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Special Issue 13, October 2016

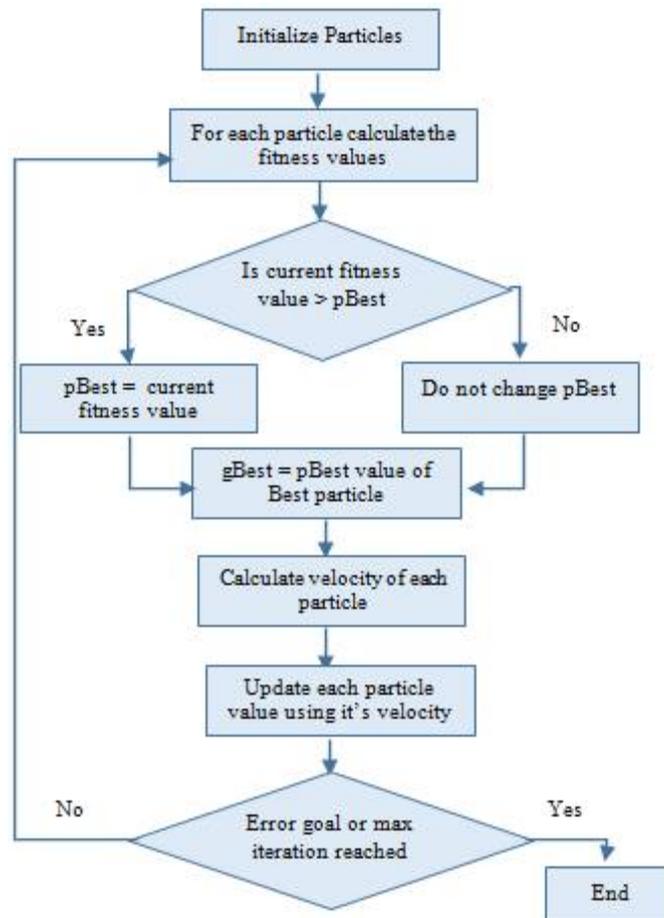


Fig. 4. Flow Chart of PSO Algorithm

B. APPLICATION OF PSO ON TWO DIFFERENT SWARMS

1) Taking Voltage as Swarm.

The terminal voltage of the PV systems are grouped and represented in the form of N- dimensional row vector as

$$X_i^t = [V_1^t, V_2^t, V_3^t, \dots, V_N^t] \quad [13]$$

The objective function 'f' denoting the power output of PV cell is calculated using eqn.

$$f = V * (I_L - I_0 \left(e^{\frac{q(V+IR_s)}{nkT}} \right)) \quad [14]$$

$P(V_i) > P(V^{t-1}_i)$ is checked for above eqn.

2) Taking Duty Cycle as Swarm.

With duty cycle as swarm agent vector becomes

$$X_i^t = [d_1^t, d_2^t, d_3^t, \dots, d_N^t] \quad [15]$$

$P(d^t_i) > P(d^{t-1}_i)$ is checked for above eqn.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Special Issue 13, October 2016

IV. EXPERIMENTAL RESULTS

The number of particle swarm is set as 10, and the dimension of each particle as 1. Iteration no. is 4000. Based on eqn. (10-15), using MATLAB Simulink, PSO method has been applied on two different swarms such as voltage and duty cycle. Power vs. Voltage graph for V_Swarm and D_Swarm obtained from M-file are depicted in Fig.5, 6 respectively. From the comparative out-put it is prominent that P-V characteristic for V_Swarm is smooth but P-V characteristic for D_Swarm is affected by ripples. Fig.7,8 shows the variation of Swarm and Power with respect to Time for both Voltage and Duty Cycle taken as Swarm.

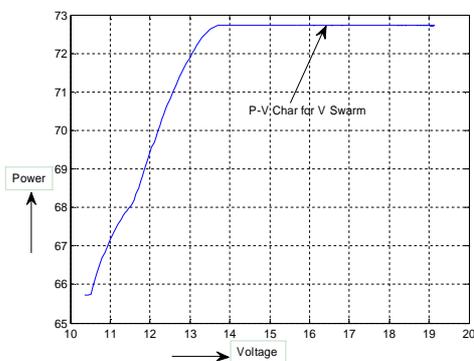


Fig. 5. MATLAB plot for Power vs. Voltage Swarm cycle Swarm

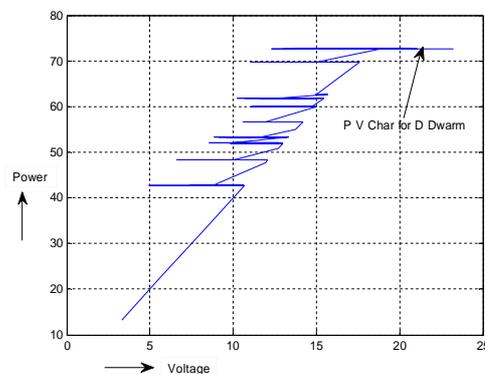


Fig. 6. MATLAB plot for Power vs. duty cycle Swarm

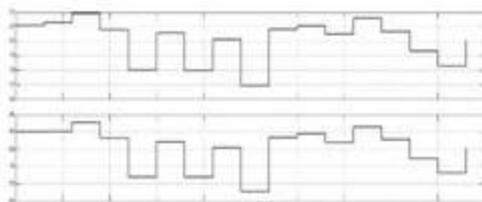


Fig. 7. Simulink plot for Voltage Swarm

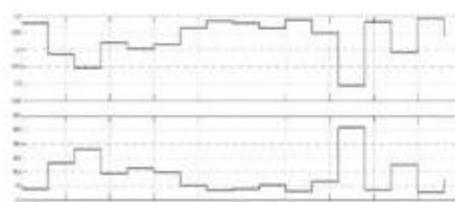


Fig. 8. Simulink plot for duty cycle Swarm

V. CONCLUSION

In this paper, a Particle Swarm Optimization (PSO) is used to track the MPP of a PV system Applying PSO. The results from Fig. 5, 6 signifies that if voltage output of PV panel is set as Swarm instead of duty cycle ripple in output power can be minimised to a large extent. Fig.7 it signifies that, while applying PSO using duty cycle as Swarm the maximum power obtained is out of manufacturing specification of the PV array. Hence if the output voltage of solar cell is used as Swarm an improvement can be done in PSO result. The main feature of the proposed method is the reduction of steady state oscillation at MPP. It has a faster tracking speed. Furthermore, the algorithm is simple and can be computed very rapidly and hence its implementation using a low cost controller is possible.

REFERENCES

- [1] O. Erdinc, M. Uzunoglu, "A new perspective in optimum sizing of hybrid renewable energy systems: Consideration of component performance degradation issue" international journal of hydrogen energy 37 (2012) 10479 e10488. ELSEVIER
- [2] H. Chen, H. Kang, A. Lee, "Strategic selection of suitable projects for hybrid solar-wind power generation systems. Renewable and Sustainable Energy Reviews" 2010;14:413e21.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Special Issue 13, October 2016

- [3] M. Veerachari, "Neural Network-Based Maximum-Power-Point Tracking of Coupled-Inductor Interleaved-Boost-Converter-Supplied PV System Using Fuzzy Controller", *IEEE Transactions on Industrial Electronics*, Vol. 50, No. 4, Aug 2003
- [4] M. A. S. Masoum, M. Sarvi, "A new fuzzy-based maximum power point tracker for photovoltaic applications", *Iranian Journal of Electrical & Electronic Engineering*, Vol. 1, January 2005.
- [5] L. Shuhui, Z. Huiying, "Energy Extraction Characteristic Study of Solar Photovoltaic Cells and Modules", 978-1-4577-1002-5/11/\$26.00 ©2011 IEEE.
- [6] A. Luque, S. Hegedus, *Handbook of Photovoltaic Science and Engineering*, New York, USA: Wiley, 2003.
- [7] V. Salas, E. Olias, A. Barrado, and A. Lazaro, "Review of the maximum power point tracking algorithms for stand-alone photovoltaic systems," *Sol. Energy Mater. Sol. Cells*, vol. 90, pp. 1555–1578, 2006.
- [8] T. ESRAM and P. L. Chapman, "Comparison of photovoltaic array maximum power point tracking techniques," *IEEE Trans. Energy Convers.*, vol. 22, no. 2, pp. 439–449, Jun. 2007.
- [9] M. A. Vitorino, L. V. Hartmann, A. M. N. Lima, and M. B. R. Correa, "Using the model of the solar cell for determining the maximum power point of photovoltaic systems," in *12th Eur. Conf. Power Electron. Appl.*, 2007, pp. 1–10.
- [10] T. T. N. Khatib, A. Mohamed, N. Amim, and K. Sopian, "An improved indirect maximum power point tracking method for standalone photovoltaic systems," *World Sci. Eng. Acad. Soc.*, pp. 56–62, 2010.
- [11] Md. A. S. Masoum, H. Dehbonei, and E. F. Fuchs, "Theoretical and Experimental Analyses of Photovoltaic Systems With Voltage- and Current-Based Maximum Power-Point Tracking" *IEEE TRANSACTIONS ON ENERGY CONVERSION*, VOL. 17, NO. 4, DECEMBER 2002.
- [12] T. Hiyama, S. Kouzuma, and T. Iimakudo, "Identification of optimal operating point of PV modules using neural network for real time maximum power tracking control," *IEEE Trans. Energy Conversion*, vol. 10, pp. 360–367, June 1995.
- [13] T. Hiyama and K. Kitabayashi, "Neural network based estimation of maximum power generation," *IEEE Trans. Energy Conversion*, vol. 12, pp. 241–247, Sept. 1997.
- [14] I. H. Altas and A. M. Sharaf, "A novel on-line MPP search algorithm for PV arrays," *IEEE Trans. Energy Conversion*, vol. 11, pp. 748–754, Dec. 1996.
- [15] C. Hua, J. Lin, and C. Shen, "Implementation of a DSP-controlled photovoltaic system with peak power tracking," *IEEE Trans. Ind. Electron.*, vol. 45, pp. 99–107, Feb. 1998.
- [16] J. H. R. Enslin and D. B. Snyman, "Combined low-cost, high-efficient inverter, peak power tracker and regulator for PV applications," *IEEE Trans. Power Electron.*, vol. 6, pp. 73–82, Jan. 1991.
- [17] P. Wolfs, Q. Li, "A Current-Sensor-Free Incremental Conductance Single Cell MPPT for High Performance Vehicle Solar Arrays"
- [18] A. Safari and S. Mekhilef, "Simulation and hardware implementation of incremental conductance MPPT with direct control method using cuk converter," *IEEE Trans. Ind. Electron.*, vol. 58, no. 4, pp. 1154–1161, Apr. 2011.
- [19] C. S. Chin, P. Neelakantan et.al, "Fuzzy Logic Based MPPT for Photovoltaic Modules Influenced by Solar Irradiation and Cell Temperature" 2011 UKSim 13th International Conference on Modelling and Simulation.
- [20] R. L. Welch, G. Kr. Venayagamoorthy, "Energy dispatch fuzzy controller for a grid-independent photovoltaic system", *Energy Conversion and Management* 51 (2010) 928–937, ELSEVIER.
- [21] K. Karabacak, N. Cetin, "Artificial neural networks for controlling wind-PV power systems: A review", *Renewable and Sustainable Energy Reviews* 29(2014)804–827 ELSEVIER
- [22] K. Punitha, D. Devaraj, S. Sakthivel, "Artificial neural network based modified incremental conductance algorithm for maximum power point tracking in photovoltaic system under partial shading conditions" *Energy* 62 (2013) 330e340 ELSEVIER.
- [23] N. H. Saad, A. A. Sattar and A. M. Mansoor, "ARTIFICIAL NEURAL CONTROLLER FOR MAXIMUM POWER POINT TRACKING OF PHOTOVOLTAIC SYSTEM", (MEPCON'2006).
- [24] V. Phimmasonel, Y. Kondo, T. Kamejima, M. Miyatake, "Verification of Efficacy of the Improved PSO-based MPPT Controlling Multiple Photovoltaic Arrays," *IEEE PEDS 2011*, Singapore, 5 - 8 December 2011.
- [25] K. Ishaque and Z. Salam, "An improved modeling method to determine the model parameters of photovoltaic (PV) modules using differential evolution (DE)," *Solar Energy*, vol. 85, pp. 2349–2359, 2011.
- [26] K. Ishaque, Z. Salam, Md. Amjad, and S. Mekhilef, "An Improved Particle Swarm Optimization (PSO)-Based MPPT for PV With Reduced Steady-State Oscillation" *IEEE TRANSACTIONS ON POWER ELECTRONICS*, VOL. 27, NO. 8, AUGUST 2012.
- [27] G. Walker "Evaluating MPPT converter topologies using a MATLAB PV model", *Journal of Electrical & Electronics Engineering*, Australia; Volume 21, Issue 1; 2001; 49-55.