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Design and Analysis of Hybrid Optimization Technique for Maximum Power Tracking in PV under Uniform and Partial Shading Condition

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Abstract:
Since the power–voltage characteristic curve of photovoltaic (PV) arrays has multiple peaks under partially shaded conditions, the conventional maximum power point tracking (MPPT) control methods will fail to work. However, the particle swarm optimization (PSO) algorithm is very suitable to solve the multi-extreme optimization problem. Hence, this paper proposes a new algorithm search method PSO and FFA to track the maximum output power of photovoltaic arrays. Finally, the performance of the proposed model is verified by simulations. From the results, it is revealed that the proposed topology exhibits higher tracking power than the conventional one.
***Keywords**: PSO, FFA, PV, MPPT*

INTRODUCTION

As the solar energy is available in nature and due to its inexhaustible availability, it has become one of the most promising renewable energies. It is envisaged to be a popular source of renewable energy due to several advantages, low operational cost, almost maintenance free and environmentally friendly. Despite the high cost of solar modules, PV power generation systems, in particular the grid-connected type, have been commercialized in many countries because of its potential long-term benefits. However, to optimize the utilization of large arrays of PV modules, maximum power point tracker (MPPT) is normally employed in conjunction with the power converter (dc–dc converter and/or inverter). The objective of MPPT is to ensure that the system can always harvest the maximum power generated by the PV arrays. However, due to the varying environmental condition, namely temperature and solar insolation, the *P–V* characteristic curve exhibits a maximum power point (MPP) that varies nonlinearly with these conditions—thus posing a challenge for the tracking algorithm[1].

To date, various MPP tracking methods have been proposed. These techniques vary in complexity, accuracy, and speed. Among the renowned power maximizing methods are Perturb and Observe (P&O) and/or hill climbing and incremental conductance (IC). These techniques, nonetheless, fail to track maximum power point when the insolation level is not consistent for all PV solar cells or the panel is partially shaded. P&O technique frequently leads to wrongful conclusion, oscillation around the maximum power point, and it generally needs to link one or many modifications for general usage. Incremental conductance techniques overcome these shortfalls of Perturb and Observe techniques but need relatively elaborate detection devices, and the choice of the step and threshold is also distressing[2].

In an effort to overcome aforementioned disadvantages, several pieces of research have used

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artificial intelligence approach such as fuzzy logic controller (FLC) and neural network (NN). Although these methods are effective in dealing with the nonlinear characteristics of the *I–V* curves, they require extensive computation. For example, FLC has to deal with fuzzification, rule base storage, inference mechanism, and defuzzification operations[14]. For NN, the large amount of data required for training are a major source of constraint[13]. Furthermore, as the operating conditions of the PV system vary continuously, MPPT has to respond to changes in insolation and temperature variations in real time. Clearly, a low-cost processor cannot be employed in such a system.

An alternative approach is to employ evolutionary algorithm (EA) techniques[6-8,10,11,12]. Among the EA techniques[16,17], particle swarm optimization (PSO) is highly potential due to its simple structure, easy implementation, and fast computation capability[15]. Since PSO is based on search optimization, in principle, it should be able to locate the MPP for any type of $P-V$ curve regardless of environmental variations. Realizing these advantages, several researchers have employed this technique to improve the MPP tracking[3-5].

Although PSO methods introduced higher possibilities to reach global peak under shade conditions, their convergence to the optimal operating region is not always guaranteed[9].

To capitalize that particular advantage, this paper proposes an improved MPPT method based on a FFA algorithm.

II.MODELING OF PV ARRAY

The basic building block of PV arrays is the solar cell. The solar cell is nothing but a p-n junction, thus it converts light energy into electricity. When the PN junction is exposed to light, photons with energy greater than the gap of energy are absorbed, causing the emergence of electron-hole pairs. These carriers are separated under the influence of electric fields within the junction, creating a current that is proportional to the incidence of solar irradiation[18]. The equivalent circuit of a PV cell is stated in Figure 1.

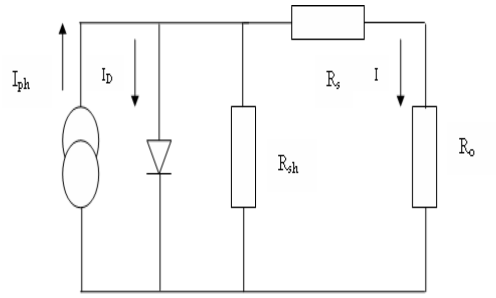

Figure 1. Equivalent circuit of a PV cell

PV cells are connected in large unit to form a PV module. Thus PV module connected in series-parallel configuration forms a PV array. The mathematical model of a PV array is expressed by the following equation:

$$I = n_p I_{ph} - n_p I_s \left[exp\left(\frac{q}{KTA}\right) * \left({}^{V}/_{n_s}\right) - 1 \right] \qquad (1)$$

where

I_{ph} - photo current

I - output current of PV array

V - output voltage of PV array

n_s - number of cells in series

n_p - number of cells in parallel

q - charge of an electron

K - Boltzmann’s constant [8.62 x 10-5 eV/K]

A - ideality factor of the p-n junction. It ranges between 1-5.

T - cell temperature (K)

I_{rs} - cell reverse saturation current.

The cell reverse saturation current I_{rs} varies with temperature according to the following equation:

$$I_{rs} = I_{ff}\ [T/T_f] \wedge 3\exp\left(\frac{qE_G}{KA[(1/T_f)-1/T]}\right) \qquad (2)$$

$$V_i^{(t+1)} = \omega \times V_i^{(t)} + c_1 \times r_1 \times (P_i^{best} - X_i^{(t)}) + c_2 \times r_2 \times (G^{best} - X_i^{(t)})$$

where

T_r- reference temperature,

I_{rr}-reverse saturation temperature at T_r

E_G- band gap of the semiconductor used in the cell.

The photo current I_{ph} depends on the solar radiation and cell temperature as follows:

$$I_{ph} = [I_{scr} + k_i(T - T_r)]s/100 \qquad (3)$$

where

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I_{scr}- short-circuit current at reference temperature [3.52A],

K_i - short circuit current temperature coefficient and

s -solar radiation in mW/cm^3.

Thus the calculated PV power can be obtained using:

$$P = IV = n_p I_{ph} V[(q/KTA)*(V/n_s) - 1] \qquad (4)$$

The power delivered by PV system dependents upon the irradiance, temperature and the current drawn from the cells[19]. Some applications such as putting power on the grid, charging batteries, or powering an electric motor demand more power than the PV system. In such cases, a power conversion system is needed to maximize the power obtained from the PV system. There are many different techniques to maximizing the power obtained from the PV system. Depending upon the irradiance and the application, the power conversion engineer has to evaluate the various options. Maximum Power Point Tracking (MPPT) is one of the technique used to obtain the maximum power from the PV system.

III.PROPOSED MPPT TOPOLOGY

Particle Swarm Optimization

PSO was proposed in 1995 by Kennedy and Eberhart The mechanism of PSO is inspired from the complex social behavior shown by the natural species. For a D-dimensional search space the position of the ith particle is represented as Xi = (xi1,xi2,..xiD). Each particle maintains a memory of its previous best position Pi = (pi1, pi2… piD) and a velocity Vi = (vi1, vi2,…viD) along each dimension . At each iteration, the P vector of the particle with best fitness in the local neighborhood, designated g, and the P vector of the current particle are combined to adjust the velocity along each dimension and a new position of the particle is determined using that velocity. The two basic equations which govern the working of PSO are that of velocity vector and position vector are given by:

$x_i^{(t)}$ - the present position of the particle i at iteration t

t -Iteration pointer

p_i^{best} - the best position of the particle i until iteration t

G^{best}-the global best position of entire swarm until iteration t

c_1, c_2 - the acceleration coefficients varies between 0 and 4

$v_i^{(t)}$ -the velocity between the step size $x_i(t)$ and $x_i(t+1)$

ω -the inertia weight/damping factor which decreases from

0.9 to 0.4 used to control the contact of new velocity with its previous velocity

r_1,r_2-Random variables with a range of [0, 2]

The inertia weight ω is calculated by the following equation.

$$\omega = \omega_{\max} - \frac{\omega_{\max} - \omega_{\min}}{iter_{\max}} \times iter$$

where

ω_{max} - initial weight

ω_{max} - final weight

$iter_{max}$ - maximum iteration number

iter - current iteration number

A new velocity is calculated in the direction of p_i^{best} and G^{best} to execute a change in the current search point (Swagatam Das et al. 2005). Every particle attempts to migrate from its current position to the new position by using the modified velocity. The parameter setting of PSO is depicted in table 1.

Table 1. Parameter setting of the PSO-based MPPT

Parameter	Value
Number of particles	3
Minimum duty cycle	0.02
Maximum duty cycle	0.98
Sampling time	0.1s
Maximum iteration	3
$W_{\max}$	1.0
$W_{\min}$	0.1
$C1_{,\min}$	1

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$C1_{,max}$	1.2
$C2_{,min}$	1
$C2_{,max}$	1.6

The flowchart the PSO algorithm for MPPT is shown in Figure 2.

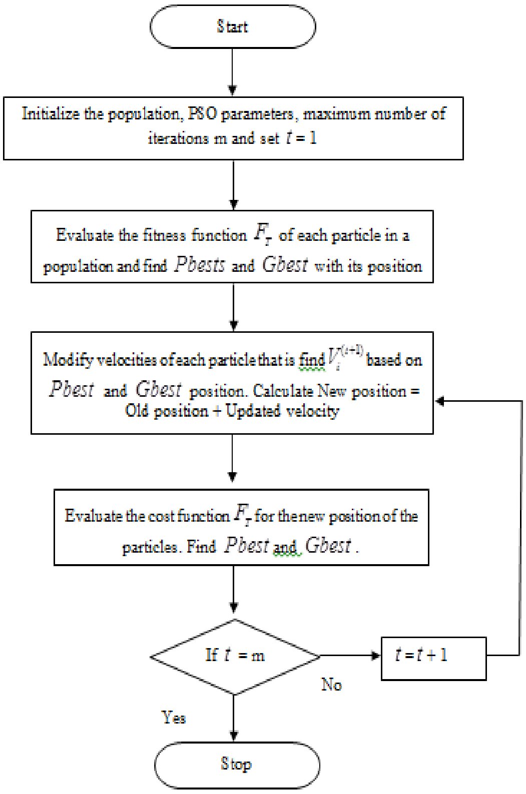

Figure 2. Implementation of PSO based MPPT

Firefly Algorithm

The FA is a population-based optimization and is introduced by Yang. This optimization algorithm is inspired by the movement of lightning bugs-commonly known as fireflies. The flashing light of fireflies is an amazing sight in the summer sky in the tropical and temperate regions. Two fundamental functions of such flashes are to attract mating partners and to attract potential prey. In addition, flashing may also serve as a protective warning mechanism. The rhythmic flash, the rate of flashing and the amount of time form part of the signal system that brings both sexes together. For simplicity in describing Firefly Algorithm, the following three assumptions are made:

1) All fireflies are unisex so that one firefly will be attracted to other fireflies regardless of their sex;

2) The attractiveness between two fireflies is proportional to relative brightness and the less brighter one will move toward the more brighter one. If there is no brighter one in a firefly colony, each one will move randomly

3) The brightness of a firefly is affected or determined by the landscape of the objective function. For a maximization problem, the brightness can simply be proportional to the value of the objective function. Let i and j be two fireflies positioned at Xi and Xj , respectively. The parameter setting of FFA is depicted in table 2.

Table 2. Parameters chosen of firefly Algorithm

S.No.	Parameters	Values
1	Number of fireflies	30
2	Maximum iteration	200
3	Alpha (α)	0.24
4	Beta (β)	0.18
5	Gamma(γ)	1

The flowchart the FFA algorithm for MPPT is shown in Figure 3.

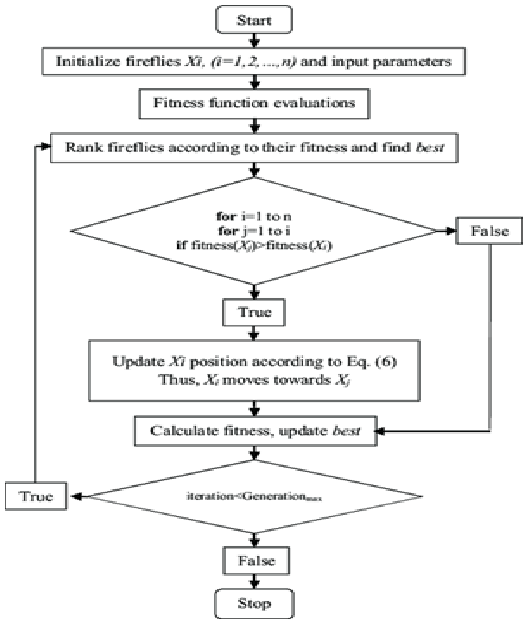

Figure 3. Implementation of FFA based MPPT

IV.SIMULATION RESULTS AND DISCUSSION

To demonstrate the effectiveness of PSO and FFA based MPPT, simulations are carried out under Uniform irradiation and is depicted in table 3.

Table 3. Simulation model parameters of 100W photovoltaic

module

Parameter	Value
Maximum Power (P_{max})	100W
Voltage at P_{max} (V_{max})	17.3V
Current at P_{max} (I_{max})	5.79A
Open circuit Voltage (V_{oc})	20.76V
Short circuit Current (I_{sc})	6.87A
Number of cells in series (N_s)	36
Number of cells in parallel (N_p)	1

The converter operated in continuous conduction mode where their design specifications (DC-DC boost converter) are switching frequency-10 kHz, capacitor C-100uF and inductor L of 2000mH respectively.

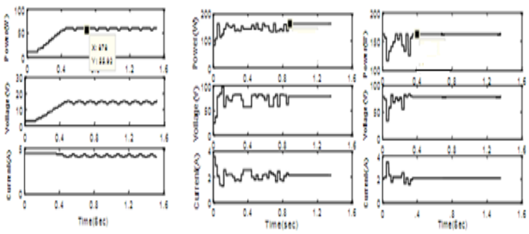

Fig. 4. Simulated Results of Power, Voltage and Current waveform of proposed topologies under uniform radiation level

Simulated results for of all three proposed algorithm under uniform irradiation condition isshown in Fig.4(a), (b) and (c) respectively. From the above results, it is inferred that FFA is faster than P&O and PSO. Furthermore, PSO takes around 10 iterations, whereas FFA takes just 4 iterations to reach global point. However the steady state oscillation and convergence time taken by PSO method is comparatively high than FFA.

Table 4.Comparison Table

Methods	Power	Voltage	Current	% Efficiency
P& O	55.92	40	4.8	80
PSO	161	75	2.5	97
FFA	162.32	77	2.2	98

IV.CONCLUSION

In this paper a new approach for MPPT using PSO and FFA is proposed. The results show that, the FFA greatly shortens the searching time, reduces the fluctuation of output waveform and improves the efficiency through particles dormancy and activation control, optimal number of particles algorithm and search sequence selection than PSO and P and O algorithm. This proposed algorithm model has good performance no matter how complex shaded conditions the PV arrays are under.

REFERENCES

1. Ram, J. Prasanth, T. SudhakarBabu, and N. Rajasekar. "A comprehensive review on solar PV maximum power point tracking techniques." Renewable and Sustainable Energy Reviews 67 (2017): 826-847.
2. Ram, J. Prasanth, N. Rajasekar and Masafumi Miyatke. " Design and overview of maximum power point tracking techniques in wind and solar photovoltaic systems: A review" Renewable and Sustainable Energy Reviews 73 (2017): 1138-1159
3. Babu, T. Sudhakar, K. Sangeetha, and N. Rajasekar. "Voltage band based improved particle swarm optimization technique for maximum power point tracking in solar photovoltaic system." Journal of Renewable and Sustainable Energy 8.1 (2016): 013106.
4. Rajasekar, N., et al. "Application of modified particle swarm optimization for maximum power point tracking under partial shading condition." Energy Procedia 61 (2014): 2633-2639
5. T.SudhakarBabu, N.Rajasekar, K.Sangeetha, Modified Particle Swarm Optimization technique based Maximum Power Point Tracking for uniform and under partial shading condition, Applied Soft Computing 34(2015)613-624.
6. Ram, J. Prasanth, and N. Rajasekar. "A novel Flower Pollination based Global Maximum Power Point method for Solar Maximum Power Point Tracking." IEEE Transactions on Power Electronics (2016).

7. Ram, J. Prasanth, and N. Rajasekar. "A new global maximum power point tracking technique for solar photovoltaic (PV) system under partial shading conditions (PSC)." Energy (2016).
8. ChakkarpaniManickam, Guru Raghav Raman, Guru Praanesh Raman, SaravanaIllangoGanesan, and Chilakapati Nagamani, “A Hybrid Algorithm for Tracking of GMPP Based on P&O and PSO with reduced Power Oscillations in String Invertor”. IEEE Transactions on Industrial Electronics DOI 10.1.109/TIE.2016.2590382.
9. RezaeeJordehi, Enhanced leader PSO(ELPSO): A new PSO variant for solving global optimisation problems, Applied Soft Computing 26(2015)401-417.
10. Ram, J. Prasanth, et al. "A new hybrid bee pollinator flower pollination algorithm for solar PV parameter estimation." Energy Conversion and Management 135 (2017): 463-476.
11. Babu, T. Sudhakar, et al. "Parameter extraction of two diode solar PV model using Fireworks algorithm." Solar Energy 140 (2016): 265- 276..
12. N. Rajasekar., Neeraja Krishna Kumar, Rini Venugopalan., Bacterial Foraging Algorithm based solar PV parameter estimation, Solar Energy, vol. 97, 2013, pp. 255-265.
13. K. Rai, N. D. Kaushika, B. Singh, and N. Agarwal, Simulation model of ANN based maximum power point tracking controller for solar PV system, Solar Energy Mater. Solar Cells, vol. 95, 2011, pp. 773–778.[7]
14. N. Alajmi, K. H. Ahmed, S. J. Finney, and B. W.Williams, Fuzzylogic-control approach of a modified hill-climbing method for maximum power point in microgrid standalone photovoltaic system, IEEE Transactionson Power Electronics, vol. 26,no. 4, Apr. 2011, pp. 1022–1030.
15. KashifIshaque, Zainal Salam, Muhammad Amjad and SaadMekhilef, An improved particle swarm optimization (PSO)-based MPPT for PV with reduced steady state oscillation, IEEE Transactions on Power Electronics, vol. 27, no. 8, Aug. 2012,pp. 3627-3638.
16. Yosura Shaiek., Mouna Ben Smida., Comparison between conventional methods and GA approach for maximum power point tracking of shaded solar PV generators, Solar Energy, vol. 90, 2013, pp. 107-122.
17. Besheer.A.H.,AdlY.M.,Ant Colony System Based PI Maximum Power Point Tracking for Stand Alone Photovoltaic System, IEEE., 2012.
18. Villalva M.G., Gazoli J.R., Filho E.R., Comprehensive approach to modeling and simulation of photovoltaic arrays, IEEE Transactions on Power Electronics, vol. 24, No. 5, 2009, pp. 1198-1208.
19. Villalva M.G., Gazoli J.R., Filho E.R., Comprehensive approach to modeling and simulation of photovoltaic arrays, IEEE Transactions on Power Electronics, vol. 24, No. 5, 2009, pp. 1198-1208.
20. K.S. Tey, S. Mekhilef, H.T. Yang, M.K. Chuang, A differential evolution based MPPT method for photovoltaic modules under partial shading conditions, Int. J. Photoenergy 2014 (2014)