An Approach of FLC-PSO based Hybrid Control Algorithm for Optimized MPPT in PV- Systems

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Abstract— ***This paper presents an efficient and accurate approach of fuzzy logic control (FLC)- particle swarm optimization (PSO) based optimized hybrid control algorithm for maximum power point tracking (MPPT) in photo voltaic (PV)- Systems. In PV based power generation systems, MPPT plays a key role to track the maximum power from the input source throughout the operations and PSO algorithm enhances the optimized operation. According to the proposed approach, FLC is implemented to track MPPT and maximum and for further improvement in MPPT is achieved by using PSO optimization technique which gives optimal value by computing duty cycle ratio. The aim of the proposed model algorithm is to track the maximum power during environmental conditions variations, reduce the steady state oscillations, and optimized operation.***

Index Terms— Renewable energy sources (RES), photo voltaic (PV), maximum power point tracking (MPPT), fuzzy logic control (FLC), perturb and observe (P&O), optimization techniques, particle swarm optimization (PSO).

I. INTRODUCTION

Photovoltaic (PV) systems are considered as most efficient leading resource because of its simple architecture. [1]- [3]. Maximum power point tracking (MPPT) topologies are used widely in renewable energy source based power generation systems. Various techniques have been discussed in last decade to address the issue of power tracking and maximizing the power tracking resulting in improved performance of the photovoltaic systems. Perturb and observe (P&O) algorithm is one of the popular algorithm used to obtain the MPPT as it is simple and fast in execution. For more accuracy fuzzy logic controllers (FLC) were replacing the conventional proportional integral (PI) controllers. Various MPPT techniques were reported in literature [4]-[14].

In optimization techniques, particle swarm optimization (PSO) is more popular. However, to get the optimization of the considered system , there are some more methods such as linear programming method (LPM), enumerative method (EM), balanced generation and load demand method, genetic algorithm (GA), iterative algorithm (IA), particle swarm optimization (PSO) has been reported [14]-[15]. In view of [16]-17], because of simplicity, high convergence rate, minimal storage requirement and ease of use with particle swarm optimization (PSO) method became popular.

Rest of this paper is organized as a brief introduction to importance of PV based systems, role of MPPT algorithms in renewable energy systems and sustainable implementation of optimization techniques in renewable energy systems has given in section I. PV systems designing aspects, MPPT controlling principles with FLC and optimization of operation with PSO algorithm is given in Section. Finally conclusion and scope of the future work is given in Section. III.

II. CONTROL ALGORITHM IMPLEMENTATION OF PROPOSED SYSTEM

This section deals with the FLC-PSO hybrid based control algorithm for optimized MPPT in PV- systems. First of all, modeling of PV array and its mathematical model is given. In the next stage, P&O – FLC algorithm is given and finally PSO is present to obtain the optimal value of maximum power point to the given PV array system.

Design Aspects of PV- Array System

In this subsection, PV array modeling is presented. The equivalent circuit of a PV cell is given by Fig.1., the related responses are given by equations (1)-(7) [18]-[23]. Nomenclature of the PV array is given by Table. I

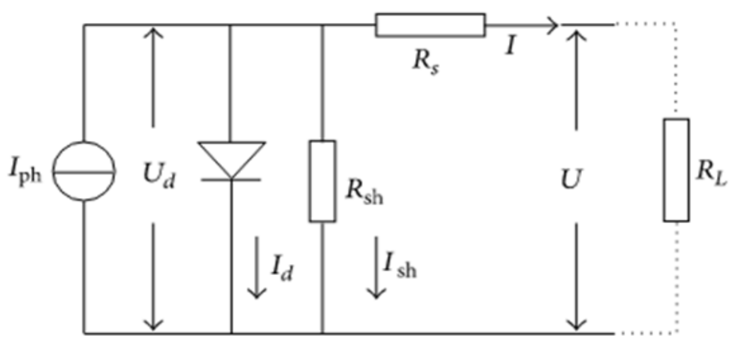

Fig.1. Equivalent circuit of a PV cell

For any ideal cell, output current can be expressed using Kirchhoff's current law. The mathematical expression of cell current is given by equation. (1).

$$I = I_{ph} - I_d - I_{sh} \quad (1)$$

$$I_d = I_O \left[exp\left(\frac{q\mathcal{U}_d}{\mathcal{F}k\mathcal{T}_c}\right) - 1 \right] \quad (2)$$

Whereas $\mathcal{U}_d$ can be computed using Kirchhoff's voltage law.

$$\mathcal{U}_d = I.R_s + \mathcal{U} \quad (3)$$

$$I = I_{ph} - I_O \left[\exp\left(\frac{q(\mathcal{U} + \mathcal{R}_s.I)}{k\mathcal{F}\mathcal{T}_c\mathcal{N}_s}\right) - 1 \right] - \frac{(I.\mathcal{R}_s + \mathcal{U})}{\mathcal{R}_p} \quad (4)$$

$$I = I_{ph} - I_O \left[\exp\left(\frac{q(\mathcal{U} + \mathcal{R}_s.I)}{k\mathcal{F}\mathcal{T}_c\mathcal{N}_s}\right) - 1 \right] \quad (5)$$

$$I_O = \exp\left[\frac{q\mathcal{E}_g\left(\frac{1}{\mathcal{T}_r} - \frac{1}{\mathcal{T}_c}\right)}{k\mathcal{F}}\right].I_{ro}\left(\frac{\mathcal{T}_c}{\mathcal{T}_r}\right)^3 \quad (6)$$

$\mathcal{E}_g$is the measurement of band-gap energy of the semiconductor present in the PV cell and saturation current of the diode is compute at 25^o which is denoted by I_{ro} and can be computed as presented in Eq. (8).

$$I_{ro} = \frac{I_{sc}}{\left[\exp\left(\frac{q\mathcal{U}_{oc}}{k\mathcal{F}\mathcal{T}_r\mathcal{N}_s}\right) - 1\right]} \quad (7)$$

TABLE I
NOMENCLATURE OF THE PV-ARRAY SYSTEM

Sl. No	Symbol	Defined term
1	I_{ph}	photo current
2	I_d	diode current
3	I_{sh}	shunt resistance current
4	I_{sc}	short-circuit current
5	$\mathcal{K}_1$	coefficient of short-circuit current
6	$\mathcal{T}_c$	cell operating temperature
7	$\mathcal{T}_r$	reference operating temperature
8	$\mathcal{R}_s$	series resistance
9	q	denotes electric charge
10	k	Boltzmann's constant
11	$\mathcal{F}$	ideal factor of diode
12	I_O	diode saturation current
13	$\mathcal{G}$	relative irradiance coefficient
14	$\mathcal{U}_{oc}$	open circuit voltage

P&O- FLC based Maximum Power Point Tracking (MPPT) Implementation

In the proposed algorithm work, perturb and observe (P&O) algorithm is used to obtain the MPPT as it is simple and fast in execution. This algorithm compares previous and present powers and voltages and adjusts the duty cycle accordingly. The flowchart of P&O algorithm is shown in Fig.1. [17].

As compared to conventional models of MPPT, FLC gives robust performance. Fuzzy logic based modules does not demand for the complete information about model and is shown by Fig.3 [12]. This controller requires voltage and current as inputs and it helps to synthesize the MPPT technique by considering temperature and solar irradiation scenario.

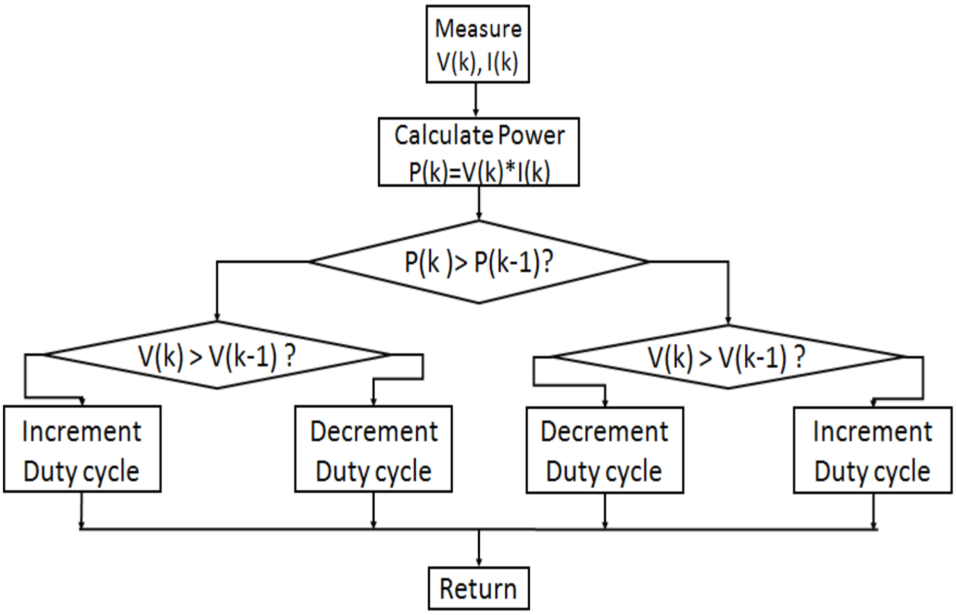

Fig. 2. Perturb and Observe (P& O) algorithm-Flowchart [17]

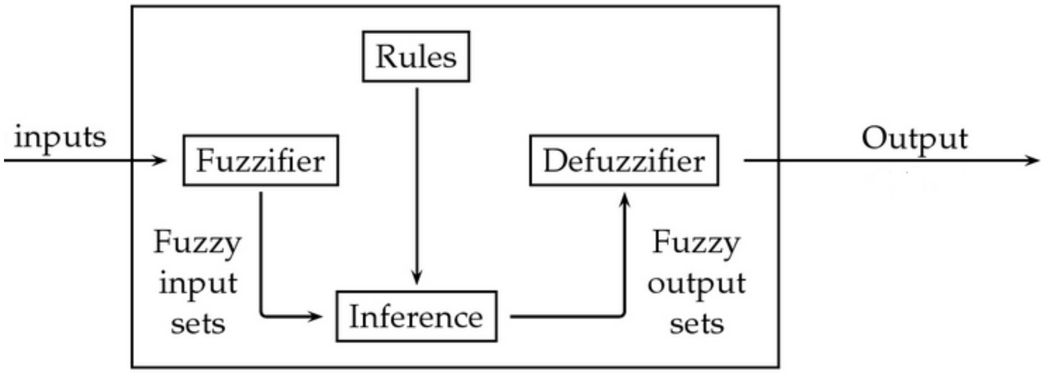

Fig.3. Block diagram of FLC [12]

PSO based MPPT Algorithm Implementation to the PV System

PSO gives a significant performance where various values of local maxima and minima are present to obtain the maximum power points. According to the PSO algorithm, it adapts the search and behavior resulting in best solution in the given search space. During this process of searching the best solution, various solutions are generated which are known as particles. Here each particle contains fitness and velocity parameters. Fitness value is also known as cost which has to be minimized and velocity directs the movement of various particles. Initially, algorithm is initialized using random positions and then better solution search approach is applied. In each iteration, velocity and position is adjusted and provides two best solutions. First solution is known as cognitive part where it follows best solution from its own solutions and other solution is known as best solution for current swarm. Generalized solution steps of PSO are given below:

Step for PSO Implementation:

Step 1-Initialize the parameter such as total number of particle and searching parameter with positions of particle and velocity of each particle.
Step 2- random formulation of particle position and velocity for each particle
Step 3- fitness computation for each particle
Step 4- Select the best fitness value as Gbest or global best
Step 5- for each iteration, update the best solution and position, velocity of each particle

Step 6- repeat step 3 and 4 until the best selection is obtained
Step 7- Select Gbest as optimized parameter for the all iterations
Step 8- Compute the output duty cycle as the optimized output

In this process of particle swarm optimization, each particle computes best particle in neighboring denoted as P_{best} and for overall process, the best solution is denoted by G_{best}. Particle position x_i can be computed as:

$$x_i^{t+1} = x_i^t + v_i^{t+1} \qquad (8)$$

Where v_i denotes the velocity of the particle.
Velocity can be computed using Eq. (9).

$$v_i^{t+1} = wv_i^t + c_1 r_1.(P_{best} i - x_i^t) + c_2 r_2.(g_{best} i - x_i^t) \qquad (9)$$

Where position of i^{th} particle is denoted by x_i, velocity is denoted by v_i, total number of iteration denoted by t, w represents the weight and $r1, r2$ are two random variable varying in the range of [0,1], $c1, c2$ denotes the cognitive and social coefficients.

III. CONCLUSION

Hence in this paper an efficient and accurate PSO based FLC-P&O MPPT algorithm has presented. Irrespective of the rating, it can be utilized for standalone or grid-connected systems of PV systems. It can be used to hybrid power generation systems. In many review research papers the individual merits of MPPT algorithms, PI, FLC and optimization techniques have given. Among those, in this paper the best practices as chosen to present the FLC-PSO hybrid based control algorithm for optimized MPPT in PV-systems.

REFERENCES

[1] [Online].Available: http://www.solarindustrymag.com/-Copyright © 2012 Zackin Publications.
[2] [Online].Available: http://www.renewableenergyworld.com.
[3] [Online].Available: https://www.solarmarket.com.au.
[4] Vijayan Sumathi , R. Jayapragash , Abhinav Bakshi and Praveen Kumar Akella "Solar tracking methods to maximize *PV* system output – A *review* of the methods adopted in recent decade" , Renewable and Sustainable Energy Reviews, Volume 74,July 2017, pp. 130-138.
[5] J. Prasanth Ram , T. Sudhakar Babu and N. Rajasekhar, "A comprehensive review on solar PV maximum power point tracking techniques", Renewable and Sustainable Energy Reviews, Volume 67, January 2017, pp. 826-847.
[6] Saleh Elkelani Babaa, Matthew Armstrong, Volker Pickert, "Overview of Maximum Power Point Tracking Control Methods for PV Systems", Journal of Power and Energy Engineering, August 2014.
[7] F. Zhang, K. Thanapalan, A. Procter, S. Carr and J. Maddy, "Adaptive Hybrid Maximum Power Point Tracking Method for a Photovoltaic System," in IEEE Transactions on Energy Conversion, vol. 28, no. 2, pp. 353-360, June 2013.
[8] J. H. Teng, W. H. Huang, T. A. Hsu and C. Y. Wang, "Novel and Fast Maximum Power Point Tracking for Photovoltaic Generation," in IEEE Transactions on Industrial Electronics, vol. 63, no. 8, pp. 4955-4966, Aug. 2016.
[9] N. E. Zakzouk, M. A. Elsaharty, A. K. Abdelsalam, A. A. Helal and B. W. Williams, "Improved performance low-cost incremental conductance PV MPPT technique," in *IET Renewable Power Generation*, vol. 10, no. 4, pp. 561-574, 4 2016.
[10] S. B. Kjær, "Evaluation of the "Hill Climbing" and the "Incremental Conductance" Maximum Power Point Trackers for Photovoltaic Power Systems," in IEEE Transactions on Energy Conversion, vol. 27, no. 4, pp. 922-929, Dec. 2012
[11] D. Sera, L. Mathe, T. Kerekes, S. V. Spataru and R. Teodorescu, "On the Perturb-and-Observe and Incremental Conductance MPPT Methods for PV Systems," in IEEE Journal of Photovoltaics, vol. 3, no. 3, pp. 1070-1078, July 2013.
[12] Nora Boumella, Juan Carlos Figueroa and Sohail Iqbal , "Enhancing Fuzzy Controllers Using Generalized Orthogonality Principle" , published by intech , capter.16.
[13] A. Al Nabulsi and R. Dhaouadi, "Efficiency Optimization of a DSP-Based Standalone PV System Using Fuzzy Logic and Dual-MPPT Control," in IEEE Transactions on Industrial Informatics, vol. 8, no. 3, pp. 573-584, Aug. 2012.
[14] Saleh Elkelani Babaa, Matthew Armstrong, Volker Pickert, "Overview of Maximum Power Point Tracking Control Methods for PV Systems", Journal of Power and Energy Engineering, August 2014.
[15] Zeineb Abdmouleh, Adel Gastli, Lazhar Ben-Brahim, Mohamed Haouari, Nasser Ahmed Al-Emadi , "Review of optimization techniques applied for the integration of distributed generation from renewable energy sources", Renewable Energy, Volume 113, December 2017, pp. 266-280.
[16] Samir M. Dawoud, Xiangning Lin, Merfat I. Okba , "Hybrid renewable microgrid *optimization techniques*: A *review*" , Renewable and Sustainable Energy Reviews, In press, corrected proof, Available online 8 September 2017 .

[17] Bala Murali Krishna. V et.al. “Cost Optimization by Integrating PV-System and Battery Energy Storage System into Microgrid using Particle Swarm Optimization”, International Journal of Pure and Applied Mathematics, Special edition, Volume.114, No. 8 2017, pp. 45-55.

[18] K. Ishaque, Z. Salam, M. Amjad and S. Mekhilef, "An Improved Particle Swarm Optimization (PSO)–Based MPPT for PV With Reduced Steady-State Oscillation," in IEEE Transactions on Power Electronics, vol. 27, no. 8, pp. 3627-3638, Aug. 2012.

[19] J.P. Fossati, A. Galarza, A. Martín-Villate, L. Font an, “A method for optimal sizing energy storage systems for microgrids”, Renew. Energy 77 (2015) 539-549.

[20] M. Zheng, C.J. Meinrenken, K.S. Lackner, “Agent-based model for electricity consumption and storage to evaluate economic viability of tariff arbitrage for residential sector demand response”, Appl. Energy 126 (2014) 297-306.

[21] S.Chowdhury , S.P. Chowdhury , G.A. Taylor and Y.H.Song , “ Mathematical Modelling and Performance Evolution of a Stand-Alone Polycrystalline PV Plant with MPPT facility” , 2008 IEEE , pp 1-8.

[22] H Bellia , RamdaniYoucef , Moulay Fatima , “A detailed modeling of photovoltaic module using MATLAB”, NRIAG Journal of Astronomy and Geophysics , Volume 3, Issue 1, June 2014, pp. 53-61.

[23] Xuan Hieu Nguyen and Minh Phuong Nguyen , “Mathematical modeling of photovoltaic cell/module/arrays with tags in Matlab/Simulink”, Environmental Systems Research , Springer Berlin Heidelberg publishers, DOI 10.1186/s40068-015-0047-9 , pp.1-13.