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# Modified Particle Swarm Optimization technique based Maximum Power Point Tracking for uniform and under partial shading condition

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ABSTRACT

Generation of electricity from solar energy has gained worldwide acceptance due to its abundant availability and eco-friendly nature. Even though the power generated from solar looks to be attractive; its availability is subjected to variation owing to many factors such as change in irradiation, temperature, shadow etc. Hence, extraction of maximum power from solar PV using Maximum Power Point Tracking (MPPT) method was the subject of study in the recent past. Among many methods proposed, Hill Climbing and Incremental Conductance MPPT methods were popular in reaching Maximum Power under constant irradiation. However, these methods show large steady state oscillations around MPP and poor dynamic performance when subjected to change in environmental conditions. On the other hand, bio-inspired algorithms showed excellent characteristics when dealing with non-linear, non-differentiable and stochastic optimization problems without involving excessive mathematical computations. Hence, in this paper an attempt is made by applying modifications to Particle Swarm Optimization technique, with emphasis on initial value selection, for Maximum Power Point Tracking. The key features of this method include ability to track the global peak power accurately under change in environmental condition with almost zero steady state oscillations, faster dynamic response and easy implementation. Systematic evaluation has been carried out for different partial shading conditions and finally the results obtained are compared with existing methods. In addition, simulations results are validated via built-in hardware prototype.

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## 1. Introduction

Ever growing energy demand by mankind and the limited availability of resources remain as a major challenge to the power sector industry. The need for renewable energy resources has been augmented in large scale and aroused due to its huge availability and pollution free operation. Among the various renewable energy resources, solar energy has gained worldwide recognition because of its minimal maintenance, zero noise and reliability. Because of the aforementioned advantages; solar energy have been widely used for various applications, but not limited to, such as megawatt scale power plants, water pumping, solar home systems, communication satellites, space vehicles and reverse osmosis plants [1]. However, power generation using solar energy still remain uncertain, despite of all the efforts, due to various factors such as poor conversion efficiency, high installation cost and reduced power output under varying environmental conditions. Further, the characteristics of solar PV are non-linear in nature imposing constraints on solar power generation. Therefore, to maximize the power output from solar PV and to enhance the operating efficiency of the solar photovoltaic system, Maximum Power Point Tracking (MPPT) algorithms are essential [2].

Various MPPT algorithms [3–5] have been investigated and reported in the literature and the most popular ones are Fractional Open Circuit Voltage [6–8], Fractional Short Circuit Current [9–11], Perturb and Observe (P&O) [12–17], Incremental Conductance (Inc. Cond.) [18–22], and Hill Climbing (HC) algorithm [23–26]. In fractional open circuit voltage, and fractional short circuit current method; its performance depends on an approximate linear correlation between $V_{mpp}$, $V_{oc}$ and $I_{mpp}$, $I_{sc}$ values. However, the above relation is not practically valid; hence, exact value of Maximum Power Point (MPP) cannot be assured. Perturb and Observe (P&O) method works with the voltage perturbation based on present and previous operating power values. Regardless of its simple structure, its efficiency principally depends on the tradeoff between the

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**Nomenclature**

| | |
|---|---|
| $I_{PV}$ | Current source |
| $R_s$ | Series resistance |
| $R_p$ | Parallel resistance |
| $V_D$ | diode voltage |
| $I_D$ | diode current |
| $I_0$ | leakage current |
| $V_{mpp}$ | voltage at maximum power point |
| $V_{oc}$ | open circuit voltage |
| $I_{mpp}$ | current at maximum power point |
| $I_{sc}$ | short circuit current |
| $V_{mpn}$ | nominal maximum power point voltage at 1000 W/m$^2$ |
| $N_{pp}$ | number of parallel PV modules |
| $N_{ss}$ | number of series PV modules |
| $w$ | weight factor |
| $c_1$ | acceleration factor |
| $c_2$ | acceleration factor |
| *pbest* | personal best position |
| *gbest* | global best position |
| $V_t$ | thermal voltage |
| $K$ | Boltzmann constant |
| $T$ | temperature |
| $q$ | electron charge |
| $N_s$ | number of cells in series |
| $V_{ocn}$ | nominal open circuit voltage at 1000W/m2 |
| $G$ | irradiation |
| $G_n$ | nominal Irradiation |
| $K_v$ | voltage temperature coefficient |
| $dT$ | difference in temperature |
| $R_{L\min}$ | minimum value of load at output |
| $R_{L\max}$ | maximum value of load at output |
| $R_{in}$ | internal resistance of the PV module |
| $R_{PV\min}$ | minimum reflective impedance of PV array |
| $R_{PV\max}$ | maximum reflective impedance of PV array |
| $R_o$ | equivalent output load resistance |
| $\eta_b$ | converter efficiency |

tracking speed and the steady state oscillations in the region of MPP [15]. Incremental Conductance (Inc. Cond.) algorithm works on the principle of comparing ratios of Incremental Conductance with instantaneous conductance and it has the similar disadvantage as that of P&O method [20,21]. HC method works alike P&O but it is based on the perturbation of duty cycle of power converter. All these traditional methods have the following disadvantages in common; reduced efficiency and steady state oscillations around MPP. Realizing the above stated drawbacks; various researchers have worked on applying certain Artificial Intelligence (AI) techniques like Neural Network (NN) [27,28] and Fuzzy Logic Control (FLC) [29,30]. However, these techniques require periodic training, enormous volume of data for training, computational complexity and large memory capacity.

Application of aforementioned MPPT methods for centralized/string PV system is limited as they fail to track the global peak power under partial shading conditions. In addition, multiple peaks occur in P-V curve under partial shading condition in which the unique peak point i.e., global power peak should be attained. However, when conventional MPPT techniques are used under such conditions, they usually get trapped in any one of the local power peaks; drastically lowering the search efficiency. Hence, to improve MPP tracking efficiency of conventional methods under PS conditions certain modifications have been proposed in Ref. [31]. Some used two stage approach to track the MPP [32]. In the first stage, a wide search is performed which ensures that the operating point is moved closer to the global peak which is further fine-tuned in the second stage to reach the global peak value. Even though tracking efficiency has improved the method still fails to find the global maximum under all conditions. Another interesting approach is improving the Fibonacci search method for global MPP tracking [33]. Alike two stage method, this one also suffers from the same drawback that it does not guarantee accurate MPP tracking under all shaded conditions [34]. Yet another unique formulation combining DIRECT search method with P&O was put forward for global MPP tracking in Ref. [35]. Even though it is rendered effective, it is very complex and increases the computational burden.

In the recent past, bio-inspired algorithms like GA, PSO and ACO have drawn considerable researcher's attention for MPPT application; since they ensure sufficient class of accuracy while dealing with non-linear, non-differentiable and stochastic optimization problems without involving excessive mathematical computations [32,36–38]. Further, these methods offer various advantages such as computational simplicity, easy implementation and faster response. Among those methods, PSO method is largely discussed and widely used for solar MPPT due to the fact that it has simple structure, system independency, high adaptability and lesser number of tuning parameters. Further in PSO method, particles are allowed to move in random directions and the best values are evolved based on *pbest* and *gbest* values. This exploration process is very suitable for MPPT application.

To improve the search efficiency of the conventional PSO method authors have proposed modifications to the existing algorithm. In Ref. [39], the authors have put forward an additional perception capability for the particles in search space so that best solutions are evolved with higher accuracy than PSO. However, details on implementation under partial shading condition are not discussed. Further, this method is only applicable when the entire module receive uniform insolation cannot be considered. Traditional PSO method is modified in Ref. [40] by introducing equations for velocity update and inertia. Even though the method showed better performance, use of extra coefficients in the conventional PSO search limits its advantage and increases the computational burden of the algorithm. Another approach to improve PSO with reduced steady state oscillations is proposed in Ref. [41]. Use of PSO method in conjunction with the direct duty cycle control was discussed in detail. However, system design guidelines and practical design considerations are not provided.

Even though many authors have proposed modifications to PSO method in its conventional form; less focus have been given for PSO particle initialization. In fact, particle initialization in PSO largely influences its performance. For instance, if the initialized particle is far away from the best position (based on its own experience and its neighbor), a larger change in velocity is required to move closer to the best position. But, a very large difference in the velocity might cause the particle to escape from the vicinity of the global peak. This spurs the possibility of convergence to a local peak instead of global peak which in turn lowers down the efficiency [31]. Taking this into account, in this paper an attempt is made to improve the PSO performance by incorporating an effective method to compute initial duty cycle for faster convergence, reduced steady state oscillations and minimal power fluctuations. Further, global peak is reached under varying environmental conditions.

Remaining section of the paper is organized as follows: Section 2 discusses PV modeling using single diode model and characteristics of partial shaded PV array. Section 3 deals with description about the proposed MPSO algorithm and its implementation. Simulation and experimental results are given in Section 4 along with its comparison with other conventional methods. Finally, conclusions derived are presented in Section 5.

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