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A comprehensive review on solar PV maximum power point tracking techniques

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ABSTRACT

In recent years solar energy has received worldwide attention in the field of renewable energy systems. Among the various research thrusts in solar PV, the most proverbial area is extracting maximum power from solar PV system. Application dof Maximum Power Point Tracking (MPPT) for extracting maximum power is very much appreciated and holds the key in developing efficient solar PV system. In this paper, a state of the art review on various maximum power point techniques for solar PV systems covering timeworn conventional methods and latest soft computing algorithms is presented. To date critical analysis on each of the method in terms of (1) tracking speed, (2) algorithm complexity, (3) Dynamic tracking under partial shading and (4) hardware implementation is not been carried out. In this regard the authors have attempted to compile a comprehensive review on various solar PV MPPT techniques based on the above criteria. Further, it is envisaged that the information presented in this review paper will be a valuable gathering of information for practicing engineers as well as for new researchers.

Contents

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1. Introduction

Sustainable energy resource is in high demand because of the continuous depletion in fossil fuels and oil resources. Among the available renewable energy resources, solar energy has emerged as one of the finest green energy resource and seen as a better replacement for conventional energy. The energy harvestment from solar energy played a vibrant role in the past decade in meeting the energy demand. In addition, the enriched scope and eco-friendly nature of solar energy have attracted many researchers to propose scholarly research in this area.

Though many potential research areas do exist in solar; the major research focuses concerned, but not confined to, are: (a). Evaluation of MPPT techniques [1–5], (b). Array reconfiguration [6,7], (c). Modeling of solar cell characteristics [8–16], (d). Efficiency improvement [17,18] and (e). Grid interfacing [19–21]. Since, per watt cost of solar energy is too high it is economical to try improving its performance via power converters. The use of converters in solar PV system is many fold (i) Provides isolation (ii) helpful in extracting maximum power and (iii) control can be made simple. Moreover, converters are effective means in implementing MPPT technology.

Numerous research work on MPPT for solar PV system have been proposed in last few decades and the methods developed so far can be broadly classified into (a) conventional and (b) Soft computing techniques. The conventional method comprises of Fractional short circuit (FSC) [22–24], Fractional open circuit (FOC) [25–27], Perturb and Observe [28–38], Incremental Conductance [39–47], Hill Climbing [48–50] and Global MPPT methods [47]. The main shortcoming of Fractional Short Circuit (FSC) and Fractional Open Circuit (FOC) method is that it is less accurate and these techniques are only favored in low power applications [28]. Whilst popular techniques like P&O, HC & IC are capable of tracking maximum power only under uniform irradiation and these methods utterly fails when partial shading occurs i.e., panels in an array receive unequal irradiation [29, 41, and 50]. Further, these methods show poor convergence, slow tracking speed and high steady state oscillations. Therefore to track MPP under partial shading conditions conventional methods need to fused with other methods for better performance. Meanwhile a new adaptive P&O technique having modifications from fixed step size to variable step size have been proposed in [29,30]. Even-though the above alterations have enhanced its performance but not sufficient enough under all operating conditions [32,40,49].

As an alternative to timeworn conventional methods, Soft Computing/Evolutionary Algorithms have been put forth in the field of solar PV research. Because of the numerous advantages like (i) ability to handle non linearity (ii) wide exploration in search pace and (iii) coherent skill to reach global optimal regions these methods is considered to be a prime choice for non-linear optimization. The methods that fall under soft computing techniques for MPPT application are Fuzzy Logic Control (FLC) [52–65], Artificial Neural Network (ANN) [66–76], Genetic Algorithm (GA) [77–85], Particle Swarm Optimization (PSO) [86–94], Non linear control [95], chaotic approach [96], Differential Evaluation [97,98] Cuckoo Search [102], Bee Colony Search algorithm,[103], Ant Colony Optimization [107,108], Fireflies Algorithms [113] and Random Search methods [115].

Among the soft computing methods, ANN and FLC are knowledge based system where it requires a detailed knowledge while implementing the algorithm. ANN and Fuzzy Logic are effective in tracking MPP but require large memory for training and rules implementation. In particular, the fuzzy logic method suffers from a severe drawback that the rules cannot be changed, once it is defined [4,5]. Further, these algorithms are heavily pounded in reaching global maximum under partial shaded conditions. Since the amount of training involved is quite high, it makes its implementation even more complex. In a similar way, Fibonacci [99] and DIRECT MPPT [100] based approaches faces similar drawback and made these algorithms unfeasible in reaching global optimum.

On the other hand, new era on MPPT in PV system have emerged when evolutionary algorithm was first applied for MPP tracking [4,5]. Further, it has opened up new scopes and possibilities, since these methods can handle non-linear problems very well. Among the optimization techniques, PSO method has been well received by the research community because of its simplicity, robustness and easy implementation. Moreover, with this method the problem of reaching global peak is also handled effectively. Further improvements to basic PSO method were introduced in the form of deterministic PSO, Modified PSO and Improved PSO methods in [91,93,94] respectively. In addition to PSO, new algorithms like Cuckoo Search [102]; Bee Colony [103], Ant Colony Optimization [107,108], Fireflies Algorithms [113] and Random Search [115] have also been proposed for the problem of MPP tracking.

Being realized the importance of soft computing techniques; many authors have alternatively tried combining the benefits of conventional and soft computing methods [32,46]. Under such circumstances the best operating points (V_{mp} and I_{mp}) are found using conventional methods and drawbacks like repeated perturbations and steady state oscillations are eliminated using evolutionary algorithms. Since two different approaches are employed for tracking, it increases the computational time and it necessitates for large memory requirement.

In addition to the above algorithms discussed, methods like base fixed voltage algorithm [116], current sweep method [117],