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Variable step size modified P&O MPPT algorithm using GA-based hybrid offline/online PID controller

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ABSTRACT

This paper presents a new modified Perturbation and Observation (P&O) maximum power point tracking algorithm with adaptive duty cycle step using PID controller based on genetic algorithm. The classical P&O MPPT algorithm is widely used in several applications due to its simplicity; however, P&O prone to failure especially when high changes in irradiance, oscillation around the MPP and the convergence speed. To face this challenge and in order to overcome the drawbacks of the classical P&O MPPT, a new method based on variable-step size of modified P&O MPPT method using PID controller tuned by genetic algorithm is presented. The efficiency of the proposed method has been studied successfully using a boost converter connected to a Solarex MSX-60 model. Analysis and comparison with the classical fixed step size P&O and that developed genetic variable step size are presented. The efficiency and improvements of the proposed algorithm in transient, steady-state and dynamic responses, especially under rapidly changing atmospheric conditions, related to ripple, overshoot and response time have been demonstrated. Algorithm robustness was verified using different schemes for temperature and insolation proving its ability to track the maximum power point in case of random and fast changing atmospheric conditions.

Contents

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1. Introduction

The growth of energy demand in the world is steadily increasing and new forms of energy sources must be discovered and developed in order to cover the future demands, in which the world energy demand will increase by 56% from 2010 to 2040 [1]. In this context, many countries have turned to new forms of green energy called “renewable energy” that are currently too expensive and relatively inefficient. Renewable energy is the energy which comes from natural resources such as sunlight, wind, rain, tides and geothermal heat. These resources are renewables and can be naturally replenished. Among the renewable energy sources photovoltaic (PV) energy seems to be the most promising source, due it is available almost everywhere unlike other types such as wind turbines, biomass, geothermal, waves, etc [1,2].

Recently, photovoltaic is growing quickly and becomes increasingly important factor for energetic and economic development, due to these reasons; it achieved a considerable attention as one of the low carbon most promising renewable energy alternatives. The only emissions associated with PV power generation are those from the production of its components. The Photovoltaic's performance depends mainly on the incident irradiation, weather conditions, module temperature, thermal characteristics, module material composition and mounting structure [2,3].

Photovoltaic sources are used today in many applications such as water supply in rural areas, battery charging, mountain cabins, light sources, water pumping meteorological measurement systems, island electrification, satellite power systems, etc. They have the advantage of being maintenance and pollution free but their main drawbacks are high fabrication cost, low energy conversion efficiency and nonlinear characteristics [2–4]. The efficiency of a PV system is affected mainly by three factors:

- The efficiency of the solar panel (9–17%);
- The efficiency of the inverter (95–98%);
- The efficiency of the maximum power point tracking (MPPT) algorithm (which is over 98%)[5,6].

Improvement of MPPT algorithm is the easiest factor due to its cost and it can be used even in equipments which are already in use by updating their control algorithms. Over the last few decades, considerable progress has been made in the MPPT techniques [7–10], these methods can be classified in as online or offline methods and hybrid methods [11,12]. The offline methods does not measure the actual extracted power of the PV panel and they are based on prior knowledge of the photovoltaic panel characteristics and measurements of solar irradiation, such as the short circuit current (I_{sc}) and the open circuit voltage (V_{oc}) [12–14]. These values are employed to generate the control signal necessary for driving the solar cell to its maximum power point (MPP). However, these algorithms cannot detect the maximum power point very accurately, especially during rapid variation in atmospheric conditions [12]. The online methods such as Perturb and Observe (P&O) method [8,11,15], Incremental Conductance (IC) method [8,16–18] and Hill Climbing (HC) [8,19]. The hybrid methods track the MPP with high accuracy, they consisting of two steps: the first step is used for parameter optimization such as PID, fuzzy logic controller and ANN structure. The second step uses the obtained parameter into conventional MPPT methods. Many hybrid methods have been developed such as genetic algorithm-neural networks (GA-ANN) [20,21], optimization of a fuzzy logic controller using particle swarm optimization (PSO-FLC) [22] and genetic algorithm-fuzzy logic controller (GA-FLC) [5,11,23]. Among previous MPPT method, Perturb and Observe, Incremental Conductance and Hill Climbing are the most popular and are widely applied in the MPPT controller due to their simplicity and easy implementation. These methods differ in many aspects such as complexity, sensors required, cost or efficiency, their simplicity, oscillation around the MPP, correct tracking when irradiation and/or temperature change, convergence speed, etc.

Perturb and Observe method based on fixed iteration step size has good performances. However, the main shortcoming of P&O method is that, at the steady state, the operating point oscillates around the MPP resulting in waste some amount of the available energy, the step size is increased for tracking speed-up, the accuracy is decreased and vice versa [24]. To solve the aforementioned drawbacks, modified MPPT algorithms with variable step size have been proposed for some techniques especially the modified Perturb and Observe method, Incremental Conductance MPPT method [18,24,25], in which the step size is automatically adapted according to the inherent PV panel characteristics and improve tracking accuracy as well as tracking dynamics.

A new modified P&O MPPT method with variable step size using PID controller based on genetic algorithm is proposed in this paper. The efficiency of the proposed method has been studied successfully using a boost converter connected to a Solarex MSX-60 model [26]. Results and comparative study between the classical fixed step size P&O and that developed genetic variable step size are presented, three improvements have been demonstrated: response time, overshoot and ripple. In addition, algorithm robustness was verified using different schemes for temperature and insolation proving its ability to track the maximum power point in case of random and fast changing atmospheric conditions.

2. Related works on the use of genetic algorithm in PV MPPT

In the last decade, artificial neural networks (ANNs) [5,8,27–29], fuzzy logic (FL) [8,11,23,30,31], and genetic algorithm (GA) techniques [5,8,20], known as artificial intelligence techniques have been widely used in PV systems process and components, especially under instantaneous climate changes and partially shading conditions. The major reason for this interest is that these techniques are power full and broadly applicable stochastic search and optimization techniques that really work for PV problems that are very difficult to solve by conventional techniques. GAs algorithms, as powerful and broadly applicable stochastic search and optimization techniques, are one of the most widely investigated in the few past years by researcher's community [21,31–33].

From the use of GA concept have resulting fresh research body and applications in PV systems: PV model parameters identification [33–35], PV system sizing [36], PV structure optimization [36] and PV MPPT strategies [31,32,36]. This last application had focused the attention of many researchers and engineers due to its impact on whole system performances. The MPPT, considered as the heart of PV system, adjusts the output power of inverter or DC converter in order to supply reliable energy to the load. The rest of this section constitutes a brief review of the use of GAs in PV system MPPT. Based on the use of genetic algorithm as classification criteria, we can classify this review in two categories named: indirect applications (or hybrid applications) and direct applications.

2.1. Indirect or hybrid applications

In the first category, genetic algorithm techniques are combined with others techniques such as neural networks (NN) or/and fuzzy logic controller (FLC). In this case, the parameters of neural networks and fuzzy logic controller are optimized using genetic algorithm. The GA-ANN and GA-FLC MPPT methods perform better than the conventional P&O method. They exhibit superior