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Modeling and control of grid connected intelligent hybrid photovoltaic system using new hybrid fuzzy-neural method

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Abstract

Photovoltaic (PV) system has non-linear current–voltage characteristics that generates maximum power at only one particular operating point. Irradiance and temperature variations have important role to affect the maximum power point (MPP). Diverse techniques have been introduced for tracking the MPP based on the offline and online methods. In this paper, in order to capture the maximum power, hybrid fuzzy-neural method is applied in PV system. Three case studies have implemented to show the effectiveness and superiority of the proposed method. It can be found that the hybrid fuzzy-neural controller can provide good dynamic operation, faster convergence speed, less oscillations of operating point around MPP, it tracks global maxima under different condition effectively than conventional methods. Operating point will not vary too much from MPP under quickly changing atmospheric condition and it is more effective and efficient as well as the average tracking efficiency of the hybrid fuzzy-neural is incremented by approximately two percentage points in comparison of the conventional methods. Detailed mathematical model and a control approach of a three-phase grid-connected intelligent hybrid system have proposed using Matlab/Simulink.

Keywords: Photovoltaic; Artificial neural network; Fuzzy logic controller; Genetic algorithm; Grid controller

1. Introduction

Maximum power point tracking (MPPT) is one of the important sections in PV system and plays a practical role in utilization of these systems. Each PV cell has a specific point named MPP on its operational curve (i.e. current–voltage or power–voltage curve) in which it can generate maximum power (Rezvani et al., 2015a,c; Izadbakhsh et al., 2015). Irradiance and temperature changes affect these operational curves. Therefore, the nonlinear characteristic of MPP to environment has caused to development of different MPPT techniques. In this paper a study of intelligent hybrid PV system used in the grid connected mode.

The most prevalent MPPT methods are perturb-and-observe (P&O) algorithm (Rezvani et al., 2015c), incremental conductance (IC) (Rezvani et al., 2015d), fuzzy logic controller (FLC) (Vafaei et al., 2015; Liu et al., 2015; Eltawila and Zhaob, 2013; Algazar et al., 2012), an artificial neural network (ANN) (Liu et al., 2004; Rai et al., 2011; Chaouachi et al., 2010; Kharb et al., 2014; Afsin and Kulaksiz, 2012).

P&O is the most common MPPT method in industry applications because of its proper balance between simplicity and operation. Albeit of its simplicity, the main

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drawbacks of P&O are trapping in local minima, maloperation in case of prompt changes in weather condition and even incorrect recognition of MPP path in this situation. Slow dynamic performance in case of small step sizes, low efficiency and permanent oscillation around MPP are the other defects of P&O algorithm. The efforts to resolve aforementioned troubles lead to expansion of many methods (Rezvani et al., 2015c,d).

The IC takes into account as other hill climbing method developed using the derivative of conductance (I_{pv}/V_{pp}). IC method tracks the MPP by judging whether PV system is proceeding to the right or left of MPP. Due to the complexity of decision making practice in the differentiation process a further computing of the controller is required in this method. Moreover, the IC method outputs are not obtained as desired at low irradiance level as the differentiation process becomes more difficult.

Tracking the MPP of PV module using fuzzy logic control (FLC) is became popular in the last decade. The advantages of FLC can be considered as its robustness and simple implementation. FLC is simple structure as it doesn't need knowledge of the model but requires the information regarding the operation of the model (Rezvani et al., 2015c; Algazar et al., 2012; Liu et al., 2004). FLC can be effective if parameters and membership functions are chosen through experimentation along with an expert opinion. Another drawback of FLC is the high cost of implementation which is due to the complexity of its algorithms.

New methods such as ANN have been utilized to overcome the downsides (Rai et al., 2011; Chaouachi et al., 2010; Kharb et al., 2014; Afsin and Kulaksiz, 2012). Since the ANN has the capability to be used on non-linear tasks, its usage in different areas has been growing. ANN does not require reprogramming since it is based on learning process.

In (Salah and Mohamed, 2011) FLC and ANN application on PV systems as two methods of MPPT have been presented. Inputs to the two MPPT controllers are irradiance and temperature of PV cell which estimates the optimum duty cycle corresponding to MPP as output.

Unlike the conventional search algorithms such as a GA does not trap into local minima as well as being an effective for optimization troubles. Such advantages distinguish GA from the conventional algorithms. Combining ANN and GA with the purpose of performance improvement has been presented in Afsin and Kulaksiz (2012). In this paper GA application is to boost the MPPT efficiency of a photovoltaic module on an induction motor drive. This can be done through enhancing the input dataset for a neural network model of the PV modules. A variable frequency volts-per-hertz (V/f) control technique is used to speed control the induction motor, and a space-vector pulse-width modulation (SV-PWM) method is utilised to act as a 3 phase inverter.

In Izadbakhsh et al. (2014, 2015), Rezvani et al. (2015b, c,d), Vafaei et al. (2015), Vincheh et al. (2014), GA is employed in data optimization thus the optimum values are applied for the purpose of ANN training. The outcome indicates this technique has less fluctuation when comparing to the conventional methods. The advantage of this method is operating in MPPT but many inaccuracies in the neural network training.

Results in Vincheh et al. (2014) represent a new hybrid fuzzy-neural MPPT controller. Training data of ANN are optimized using GA. A novel GA technique to accomplish the MPPT based on the cell model, also presented in Hadji et al. (2011).

Authors in Liu et al. (2015) have presented the simulation and hardware implementation of a hill-climbing (HC) modified fuzzy-logic controller MPPT control used in PV systems with the direct control method. The conventional HC method is used to improve the FLC search method and eliminate their drawbacks. In Csuo et al. (2015) has represented an equivalent circuit model of PV system, and discussed the PV grid power generation system in the MPPT control principle of the boost circuit. In Rajani and Pandya (2015) presents simulation and comparison P&O and IC MPPT algorithms for solar energy system connected to grid. Authors in Mohanty et al. (2014) compare the performance of different MPPT methods that are currently used in a solar PV system as well as represent a new MPPT method which shows better performance than conventional method. Authors in Ahmed and Salam (2015) have proposed the performance of variable step-size P&O MPPT controller as well as initially, a Matlab based photovoltaic generation system model is developed and validated. Then, variable step-size MPPT controllers are compared in terms of energy captured, rise time, settling time and steady-state tracking accuracy under various operating conditions. In (Bella, 2015) studies dye-sensitized solar cells (DSSCs) and perovskite solar cells (PSCs) for the role of leader in the field of third-generation photovoltaic technologies. In particular, such success is attributed to the introduction of polymer electrolytes and perovskites, which have recently contributed to obtaining high conversion efficiencies. In (Chen et al., 2015) studies the operation of various variable step-size P&O MPPT methods. Initially, a Matlab based PV Generation system model is developed and validated. Performance indices are also represented in this paper to enhance the reliability of the comparison.

It should be noted that the aforementioned papers are lack in evaluation of the system performance in the intelligent system and no comparison has been done between the hybrid fuzzy-neural method to conventional methods such as P&O, IC and FLC. Such a comparison could be beneficial to indicate the high performance of this method in different environmental conditions. Hence, to the best of authors' knowledge, there is none published paper presenting such framework using intelligent hybrid method for PV system in the grid connected mode. It is noted that the results confirmed the superior and effectiveness of the proposed methods. In this paper, hybrid fuzzy neural