Renewable and Sustainable Energy Reviews 82 (2018) 2202–2217

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Design and implementation of ANFIS-reference model controller based MPPT using FPGA for photovoltaic system

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ARTICLE INFO

Keywords:
Maximum Power Point Tracking (MPPT)
Adaptive Neuro Fuzzy Inference System (ANFIS)
Field Programmable Gate Array (FPGA)
Incremental conductance method
Constant voltage method

ABSTRACT

The aim of this work is to demonstrate the usefulness of Adaptive Neuro Fuzzy Inference System (ANFIS) for tracking Maximum Power Point (MPP) in stand-alone photovoltaic system. Maximum Power Point Tracking (MPPT) is one of approaches which boost efficiency of PhotoVoltaic (PV) cells by the load matching between the PV cells and the load. The key problem is that maximum power is not achieved because PV cells power is affected by weather conditions such as the solar irradiation and the temperature, thus, the MPP is changed during daylight hours and year seasons. Therefore, it is necessary to design an appropriate controller based on one of techniques to track MPP. These techniques are based on true or estimated searching mechanism to MPP. True searching mechanism based techniques like incremental conductance method and perturb and observe method are efficient but they are less stable, more oscillatory about MPP and sensitive to a high frequency noise. Generally, estimated searching mechanism based techniques like constant voltage method and fractional open circuit voltage method are less efficient, but they are stable and no sensitive to a high frequency noise. In this paper, the ANFIS-reference model method in addition to the incremental conductance method and constant voltage method have been studied, designed and implemented using Field Programmable Gate Array (FPGA) board to compare the performance of each method. The proposed ANFIS-reference model controller is efficient since it has been trained offline using Matlab tool with practical data sets. Based on our knowledge, this paper is the first paper which introduces practical implementation of ANFIS-reference model based MPPT for photovoltaic system using FPGA board. The results reveal that the ANFIS-reference model controller has more efficient and better dynamic response than the incremental conductance method and constant voltage method.

1. Introduction

Finding adequate supplies of the energy is one of human's difficult challenges for the future. Solar energy is one of renewable energy sources which can be only covered the global growing energy demand. Researchers estimate that covering 0.16% of the land on the earth with 10% efficient photovoltaic panels, is sufficient to supply 20 TW which approximately equals to twice what the world consumed from fossil energy [1].

PV cells convert the sunlight into the electric energy directly. However, low efficiency and high capital cost of PV systems are the main barriers for solar power installations [2]. The output power of the PV module is influenced by the solar irradiation and the temperature. Furthermore, the daily solar irradiation diagram has sudden variations during partly cloudy day. Fig. 1 indicates daily solar irradiation diagram in south of Iraq in sunny day (5/2/2016) and partly cloudy day (7/2/2016). MPPT is a method which used for extracting the maximum power from the PV cells and transferring the power to the load at different weather conditions (solar irradiation and the temperature), i.e. the efficiency of PV system is increased.

The aim of this work is to demonstrate the usefulness of ANFIS for tracking MPP under varying the solar irradiation level and the operating temperature by changing duty cycle ratio of a buck DC-DC converter.

DC-DC converter acts as an interface between the PV cells and the load to transfer the maximum power from the PV cells to the load. The load impedance is matched with source impedance by changing the duty cycle (ΔD) to attain the maximum power from the PV cells [3]. There are several kinds of DC-DC converter like buck (step down) which is used here, boost (step up), buck-boost and flyback converters. Fig. 2 illustrates the basic block diagram of DC-DC converter interfacing when it operates with MPPT in PV system.

Many projects and researches are focused on using ANFIS or neural network in renewable energy. Hikmet Esen et al. used ANFIS to model

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http://dx.doi.org/10.1016/j.rser.2017.08.071
Received 21 July 2016; Received in revised form 9 June 2017; Accepted 18 August 2017
Available online 01 September 2017
1364-0321/

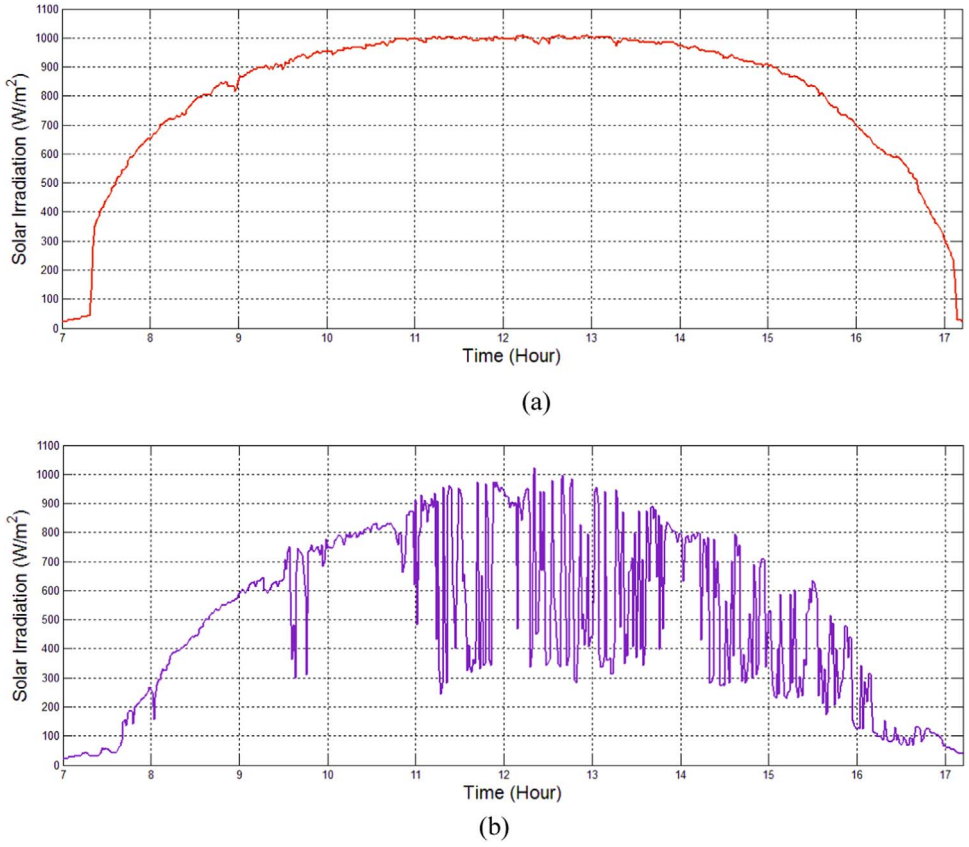

Fig. 1. Daily solar irradiation diagram in south of Iraq: (a) sunny day (5/2/2016) (b) partly cloudy day (7/2/2016).

of solar-assisted ground source heat pump system and ground-coupled heat pump system [4,5]. Also, Hikmet Esen et al. used fuzzy weighted pre-processing-based ANFIS to predict the daily performance of a ground-source heat pump system [6]. Kalika et al. presented neural fuzzy controller based MPPT. Neural Network (NN) is used to compute MPP voltage for given irradiation and temperature, while fuzzy logic controller is used to force the PV panel voltage to track MPP voltage by changing duty of buck-boost converter. The simulation results are shown that the neural fuzzy controller tracks MPP effectively under rapid variation of load, irradiation and temperature [7]. Kharb et al. designed and implemented ANFIS based MPPT. This controller is composed of ANFIS and Proportional Integral (PI) controller. The input variables of ANFIS are irradiation and temperature and the output of ANFIS is reference power (P_{max}) which is used as input with actual power to PI controller. The output of PI controller is given to duty cycle of the boost converter. Simulation results are shown that

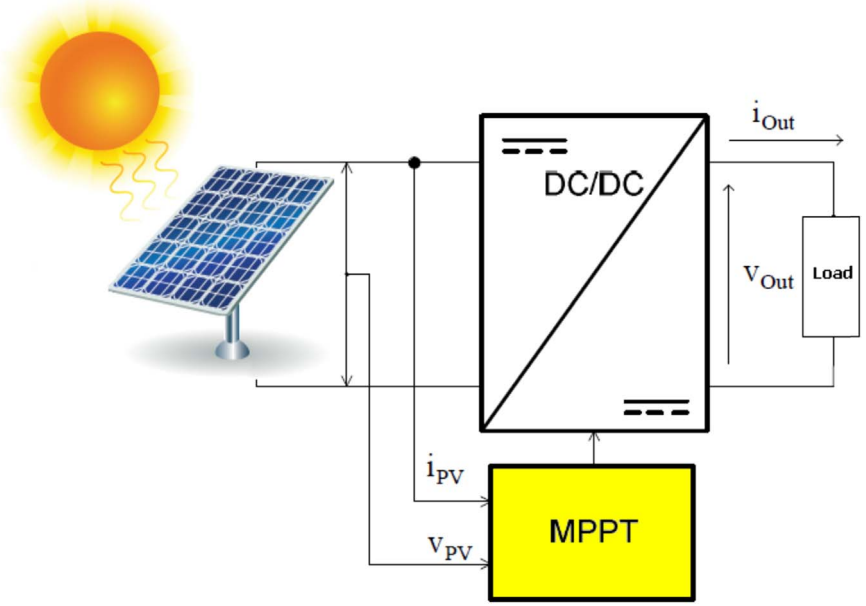

Fig. 2. Basic block diagram of DC-DC converter interface in PV system.