Energy and Buildings 84 (2014) 258–267

Contents lists available at ScienceDirect

Energy and Buildings

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

The artificial neural network model to estimate the photovoltaic modul efficiency for all regions of the Turkey

İlhan Ceylan[a], Engin Gedik[a,*], Okan Erkaymaz[b], Ali Etem Gürel[c]

[a] Faculty of Technology, Karabük University, Karabük, Turkey
[b] Engineering Faculty, BülentEcevit University, Zonguldak, Turkey
[c] Düzce Vocational High School, Düzce University, Düzce, Turkey

ARTICLE INFO

Article history:
Received 2 May 2014
Received in revised form 31 July 2014
Accepted 3 August 2014
Available online 12 August 2014

Keywords:
Solar energy
Photovoltaic
Artificial neural network

ABSTRACT

Artificial neural network (ANN) is a useful tool that using estimates behavior of the most of engineering applications. In the present study, ANN model has been used to estimate the temperature, efficiency and power of the Photovoltaic module according to outlet air temperature and solar radiation. An experimental system consisted photovoltaic module, heating and cooling sub systems, proportional integral derivative (PID) control unit was designed and built. Tests were realized at the outdoors for the constant ambient air temperatures of photovoltaic module. To preserve ambient air temperature at the determined constant values as 10, 20, 30 and 40 °C, cooling and heating subsystems which connected PID control unit were used in the test apparatus. Ambient air temperature, solar radiation, back surface of the photovoltaic module temperature was measured in the experiments. Obtained data were used to estimate the photovoltaic module temperature, efficiency and power with using ANN approach for all 7 region of the Turkey. The study dealing with this paper not only will beneficial for the limited region but also in all region of Turkey which will be thought established of photovoltaic panels by the manufacturer, researchers and etc.

1. Introduction

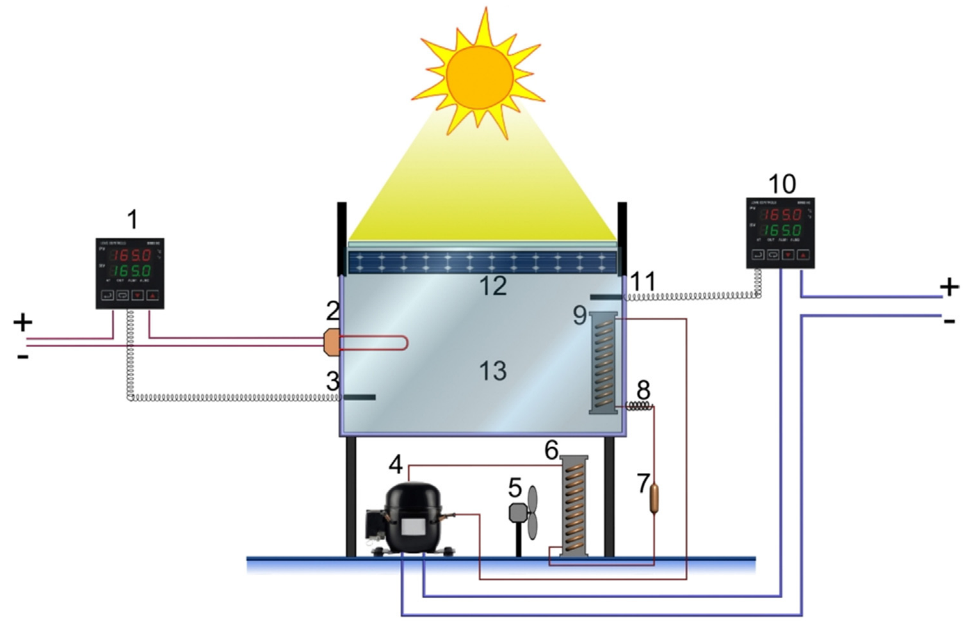
Demand for energy determining to economic, political and social events is increasing day by day in the world. Countries should have to take precautions for use their existing energy sources efficiently or search new energy sources. As it known well the decreasing amount of fossil based energy sources and its hazardous effect to the environment, the renewable energy sources make themselves attractive for research by the man. Solar energy is the important energy source placed among the renewable energy sources with its endless heat and light supply. Thermal and production of electricity are the basic applications of the solar energy.

Photovoltaic (PV) systems are commonly used all around world as shown themselves to be one of the most promising applications for dealing with electricity generation [1–3]. "In countries like Turkey, photovoltaic research and development activities are still mainly undertaken across a range of universities, government and industry facilities and the projects are mainly financed by the research program of State Planning Organization (DPT) and The Scientific & Research Council (TUBITAK)" [4]. As it like all the process PV systems efficiency are desired to be increased with done research and developments which efficiencies are between 15 and 20% now. For this purpose theoretical and experimental studies [5–9] have been carried out for increasing of PV systems efficiency which depends on insolation, atmospheric and meteorological conditions. "Module temperature is a parameter which has great influence in the behavior of a PV system, as it modifies system efficiency and output energy" [10]. Hanlin and Stein [11] have modeled the module temperature of PV system using a transient heat-flow model. Single day of measured module temperature has used simultaneous non-linear least squares regression and optimized then tested for accuracy using a year's worth of data for one location. Environmental conditions on module temperature of selected PV system in Singapore have analyzed by the Ye et al. [12]. Ceylan et al. [13] experimentally analyzed different PV/T systems for the cooling photovoltaic modules. A simple pipe was placed on PV module as a spiral heat exchanger in order to provide active cooling. Also, the system can easily be applied to large-scale systems.

Numerical or algebraic methods are the way to estimate the behavior of PV module under natural sunlight [14]. An artificial

* Corresponding author. Tel.: +90 3704338200.
E-mail addresses: ilhancey@gmail.com (İ. Ceylan), egedik@karabuk.edu.tr, gedik_engin@hotmail.com (E. Gedik).

http://dx.doi.org/10.1016/j.enbuild.2014.08.003
0378-7788/



1. Process control equipment (for heater), 2. Electrical heater, 3. Temperature sensor, 4. Compressor, 5. Fan, 6. Condenser, 7. Dryer, 8. Capillary tube, 9. Evaporator, 10. Process control equipment (for cooling), 11. Temperature sensor, 12. Photovoltaic module.

Fig. 1. The experimental system.

neural network (ANN) is a tool which is widely using to estimate the efficiency and maximum power of PV systems [15,16]. Almaktar et al. [17] presented an ANN based approach for predicting photovoltaic module temperature using meteorological variables. Ravaee et al. [18] presented a new application of ANN for modeling a Photovoltaic Thermal collector (PV/T). Ambient temperature of collector, cell and fluid temperature at duct inlet, fluid velocity in duct, solar intensity and time were used in the input layer while the thermal efficiency and electrical efficiency are outputs. Vasarevicius et al. [19] presented analysis of IncCondMPPT algorithm and comparison of operation with and without ANN. Bahgat et al. [20] presented a development and implementation of a PC-based maximum power point tracker (MPPT) for PV system using neural networks. Hadjab et al. [21] presented the results of the characterization and modeling of the electrical current-voltage and power-voltage of the photovoltaic panel BP 3160 W, using a new approach based on artificial intelligence. Reddy et al. [22] presented an application of a neural network for the identification of the optimal operating point of PV module maximum power tracking control. Kulaksız and Akkaya [23] used a genetic algorithm for improve the maximum power point tracking efficiency of a PV system with introduction motor drive by optimizing the input dataset for an ANN model of PV modules. Karatepe et al. [24] presented a neural network based approach for improving the accuracy of the electrical equivalent circuit of a photovoltaic module. Tajuddin et al. [25] presented a maximum power point tracking (MPPT) technique for photovoltaic (PV) system using a modified differential evolution (DE) algorithm. The standard DE is modified to deal with dynamic objective function problem to suit with the nonlinear time-varying MPPT nature. Mellit et al. [26] described a methodology to estimate the profile of the produced power of a 50 W p Si-polycrystalline photovoltaic module. For this purpose, two ANNs have been developed for use in cloudy and sunny days, respectively. In our previous work [27] we have investigate the PV module efficiency experimentally and we used the ANN module to estimate the module temperature for the Aegean region of Turkey and the extended version of the study is presented here which aimed to propose a model based on ANNs to estimate, under real conditions, efficiency and the maximum power of commercially available a multi crystalline silicon (mc-Si) photovoltaic module by using the outside temperature and solar radiation. For this purpose an experimental setup was designed and built. Tests were made outdoors and measured ambient air temperature, solar radiation and back surface of module temperature data were used the training of ANN, estimate the efficiency and the module temperature of PV for the all 7 region of Turkey.

2. Methodology

"Turkey has a technical power generating capacity of 4–5 MW from PV applications. Currently, the most PV applications in Turkey are used for stand-alone power systems. Depending on the developments about the price and efficiency of PV appliances, the Turkish PV market is expected to rapidly expand given the fact that there are more than 34,000 small residential areas including resort areas along the coast lines in Turkey where solar-powered electricity would be more economical than grid supply [28]". For this reason the details given in this work will be able to much beneficial for the PV market due to it composed all region of Turkey which has great solar energy potential.

An experimental system was established as can be shown in Fig. 1. The PV module was to position indoor environment with glass material of the test apparatus. Indoor environment temperature of the PV module was tried to fix as the values of 10, 20, 30 and 40 °C. To obtain constant temperature values in the indoor environment both heating and cooling systems were used. While electrical heater was using to increase the temperature, cooling system based on basic vapor compression refrigeration cycle was used to decrease the temperature in the indoor environment. It has been possible to hold desired constant temperatures with using PID control equipment. Solar radiation intensity incoming on the PV module numbered as 12 in Fig. 1 was measured with solar meter. Indoor environment temperature numbered as 13 was adjusted at desired temperature values with using number 2 and cooling equipment numbered as 4-5-6-7-8-9 in this figure. When