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Predicting efficiency of flat-plate solar collector using a fuzzy inference system

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Abstract

With the increasing world population, industrialization and comfort need of humans, energy usage is growing considerably. Nowadays most of the energy needs are obtained from fossil stratum, and hydroelectric or nuclear power plants. However, usage of these fuels has two important problems: (1) These fuels may not exist in the near future and (2) Extensive use of these fuels causes serious environmental pollution. Alternatively, solar energy that is renewable and environmentally friendly energy can be utilized. In design of such renewable energy systems, efficiency is crucial including solar water heating systems. Experiments were conducted to evaluate a flat-plate solar collector performance of thermosiphon solar water heating system during the summer season in Nicosia, North Cyprus. A fuzzy inference system was developed to predict the efficiency of the solar collector. In our fuzzy inference system, we only utilize ambiance temperature, input and output temperature of the solar heating system. The predicted values were found to be in close agreement with the experimental counterparts with 0.9469,3.13, 6.96 coefficient of determination, root mean square error and average forecasting error respectively. It was noted that the proposed fuzzy inference system can provide high accuracy and reliability for predicting the performance of a solar collector. The advantages of this approach as compared to the testing methods are speed, simplicity, and the use of expert knowledge for prediction. Hence, the soft computing approach can be a potential tool for predicting efficiency of a flat-plate solar collector.

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Keywords: Solar collector; solar water heating system; efficiency; fuzzy inference system.

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1. Introduction

Evaluation of a solar water collector's performance and its characterization from the conventional test methods that are related to the international standards needs costly test procedures and also there are limitations to meet the standard's conditions. In this respect, accurate prediction methods are valuable in predicting the performance of renewable energy systems including the collector of the solar water heaters. According to Del Chiaro and Telleen-Lawton (2007), Cyprus is one of the leaders of solar water heating systems in Mediterranean region. With all year round sunshine and second best high quality sun in Europe, Cyprus has huge solar energy generation potential. With this in mind, we investigated efficiency of a flat-plate solar collector in Cyprus. First we gathered experimental data from a flat-plate solar collector of thermo siphon solar water heating system during the summer season in Nicosia, North Cyprus. Then, we developed a fuzzy inference system to predict collector efficiency. The predicted values were found to be in close agreement with the experimental counterparts with 0.9469, 3.13 and 6.98 coefficient of determination (R^2), root mean square error (RMSE)and average forecasting error respectively. To the best of our knowledge, there have not been previous studies in Cyprus that combine experimental data obtained about solar water heating system in Cyprus and apply this data to a fuzzy inference system for predicting efficiency.

The rest of the paper is organized as follows: Section 2 discusses the related work. Section 3 explains the experimental setup and data gathering process using a flat-plate solar collector. Section 4 introduces the proposed fuzzy inference system. Section 5 is evaluations followed by conclusions.

2. Related Work

The first-ever published analysis of solar water heating (SWH) system was reported by Close (1962), who measured experimental inlet and outlet water temperature and worked on the analysis of circulation rates in natural circulation systems. Then he compared the predicted and experimental data. Kishor et al. (2010) also uses a fuzzy model representation of a solar water heating system both on analytically and experimentally obtained data in India. The aim of this paper is to predict outlet SWH temperature, which is different that the proposed fuzzy inference system since we predict the efficiency of the SWH. Dikmen et al. (2014), perform estimation and optimization of thermal performance of the evacuated tube solar collector system. In this paper, they use experimental data for the training and testing of the artificial neural networks (ANNs) and adaptive neuro-fuzzy (ANFIS) model. They forecast thermal performance of a cleared tube sun-based collector in Turkey. This is different than our approach, since we predict efficiency. Farzad et al. (2013) performed performance prediction of flat-plate solar collectors using multilayer perceptron (MLP) and ANFIS. Iran-Tehran meteorological data is used as the training data in order to train the neural network. Solar irradiance, ambient temperature, collector tilt angle and working fluid mass flow rate were used in the input layer of the network and the efficiency is presented at the output layer. Mohanty et al. (2017) utilize soft computing techniques for a solar collector that use sun oriented radiation information. They utilize diverse delicate figuring approaches like Multi layer Perceptron (MLP), ANFIS, and Radial Basis Function (RBF) for East drift area of India. It has been discovered that the delicate processing methodology is exceptionally encouraging for anticipation of sunlight based radiation and for estimation of proficiency of a sun powered level plate authority in India. Sözen et al. (2008) uses neural network approach for the determination of efficiency of flat-plate solar collectors in Turkey. They use ANN for modeling the efficiency of solar collectors with complex structures when other models may have difficulties. Logistic sigmoid transfer function was used in the network. Yaici and Entchev (2014) investigates the applicability of adaptive neuro-fuzzy inference system (ANFIS) approach for predicting the performance parameters of a solar thermal energy system. Experimental data was used for training and testing the ANFIS network model in Canada.

3. Solar Water Heating System and Experimental Data Gathering

We obtained experimental data using a flat-plate solar collector during the summer season in Nicosia, North Cyprus.The equipments that were used in the experiment for calculating the efficiency of a flat-plate collector is: Solar collector, heat exchanger, thermometers, pump, pressure regulator, water tank, expansion tank, schematic manager program for computer, PLC(Programmable Logic Controller), device of mass flow rate, sanitary installation equipments and pyranometers. The experimental setting as well as pyranometer, thermocouples' outputs