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Application of ANN technique to predict the performance of solar collector systems - A review

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ABSTRACT

The solar collector is the heart of any solar energy collection system designed for operation in the low to medium temperature ranges. So, an efficient design of solar collector system, giving optimum performance is required. Though system performance is optimized by many different techniques, however, intelligent system design is an useful technique to optimize the efficiency of such systems. One of the intelligence techniques is Artificial Neural Network (ANN), and it is used in modeling, simulation and control of the system. ANN tool is faster and more accurate to solve complex and nonlinear problems as compared to other conventional techniques. ANN technique is applied in the field of Science, Engineering, Medicine, Defense, Business and Manufacturing etc. The main task of ANN tool is training of structure, which is done by collected experimental data of solar energy systems and in this method separate programming is not required as in other conventional methods. The aim of this study is to review the applications of ANN to predict the performance of solar energy collector and to identify the research gap for future work. Published research works presented in this paper, show that the ANN technique is very appropriate tool to predict the performance of solar collector systems

1. Introduction

In view of limited reserves of fossil fuels and their depletion at a faster rate, it is necessary to develop efficient systems to use alternative sources of energy. Many types of renewable energy are available on the earth, in which solar energy is one of the most abundant and clean sources of energy. Solar energy can be utilized in two ways: active and passive. In passive solar energy utilization sun rays are directly used without the aid of any equipment, but in active way of utilization of solar energy sun rays are not directly used but some kind of mechanical equipments are needed for conversion of the solar energy into other forms of energy. Solar collectors come in the category of active way of energy utilization. In solar energy application systems solar collectors plays an important role for utilizing the solar energy. A solar collector is a special kind of heat exchanger which absorbs solar radiations and transfers the absorbed thermal energy to the flowing fluid [1].

The experimental study as well as the analytical study followed by the use of computational techniques, require a lot of time to arrive at an accurate result of a physical problem. The use of Artificial Neural Networks (ANN), on the other hand, saves time and also provides key information patterns in a multi-dimensional information domain and, therefore, this technique has been becoming increasingly popular in Science and Engineering, specially in Mechanical Engineering applications in recent years.

The major advantages of ANN technique, compared to other computational techniques are its simplicity, high speed and capability to solve complex and nonlinear relationship among the variables and the extracted data [2]. The major limitation of the method is, its requirement of the data for training of model, which is not the case with any other analytical methods.

Many researchers have used ANN in the field of energy utilization and conversion systems for performance predictions [6,7], sizing PV systems [8], refrigeration, air –conditioning and heat pump systems [9], wind and PV power systems [10], solar radiations predictions [11], hybrid energy systems [12], solid desiccant cooling systems [13] and many thermal systems [14–25]. Having gone through above literature, it is observed that no separate review on solar collector systems using ANN techniques has been reported. This paper deals with the review of literatures available on application of ANN technique for prediction of performance of solar energy collector systems such as solar water heater, solar air heater, and solar-assisted heat pumps trough collector etc.

The approach adopted in artificial neural network technique is different and superior from the traditional computing approaches. In the way it does not requires computer programing to do the solutions as required in the other numerical solutions. This technique can also be

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Nomenclature

ANN	Artificial neural network
ANFIS	Artificial neuro-fuzzy inference system
a_i	Input variables
BP	Back propagation
c_j	Center of RBF model
CGP	Polak-Ribiére Conjugate Gradient
COV	Coefficient of Variance
DXSAHP	direct expansion solar assisted heat pump
FFBP	Feed forward back propagation
FFNN	Feed forward neural network
GA	Genetic algorithm
GRNN	Generalized regression neural network
LM	Levenberg–Marquardt
M	Input neurons
MAE	Mean Absolute Error
MISO	Multiple input single output
MSE	Mean Square Error
MLP	Multi-Layered Perceptron
MLR	Multiple linear regression
MLPNN	Multi-Layered Perceptron Neural Network
N	Output neurons
NARX	Nonlinear autoregressive exogenous model
OSS	One-step secant back propagation
PSO	Particle swarm optimization
PD	Product differences
R	Correlation coefficient
RE	Relative error
RBF	Radial basis function
R^2	Coefficient of multiple determination
SAC	Solar air collector
SAH	Solar air heater
SISO	Single input single output
SCG	Scaled Conjugate Gradient
SSE	Sum Square Error
SVM	Surface volume method
SWH	Solar water heater
T_n	Number of training data
w_{ij}	weights
X_A	actual value
X_P	predicted value
x_i	input
WNN	Wavelet neural network

Greek letters

σ_j	Width of jth neuron

used to address problems that are intractable or cumbersome to solve with traditional methods. Specifically, it is suitable to find solutions for those problems which have incomplete data sets, fuzzy or incomplete information, and are highly complex and ill-defined problems, where humans usually decide on an intuitional basis. This technique has ability to self-adapt, drive powerful data and is a flexible computational tool having a high degree of accuracy in computing. Also, in case when the numerical relations between input and output variables are unknown, and cannot be incorporated, ANN is found very well suitable for modeling and prediction.

In view of the above the present work has been taken up with an aim to review the literatures related to performance predictions of solar collector systems in which ANN technique has been implemented. The present review article may be very helpful for predicting the performances of solar thermal systems in upcoming days.

1.1. Solar collector

A solar collector is a device that collects the solar radiation incidents on it, converts it into thermal energy and transfers this energy to a working fluid (air or water). The heat picked up by working fluid can also be used to charge the thermal energy storage system to use in the night. For photo voltaic (PV) utilization: PV module converts solar radiation into electrical energy. In addition to it, it also produces abundant waste heat, which can be utilized by attaching PV board with recuperating tubes filled with carrier fluids [1].

The types of solar collector are shown in Fig. 1. Solar collectors are broadly classified into two categories, such as, fixed collectors and tracking collectors. The fixed collectors are kept at rest, whereas tracking collectors track as per the movement of sun such that the incoming solar radiations always incident perpendicular to them. The tracking solar collectors are subdivided in to two categories: single and double axis tracking. The fixed collector is classified as flat plate collector, evacuated tube collector and compound parabolic collector. The single axis tracking collector is categorized into three types such as parabolic trough collector, cylindrical trough collector, and linear fresnel reflector. Again, the double axis tracking collector is subcategorized as central tower receiver, parabolic dish reflector, and

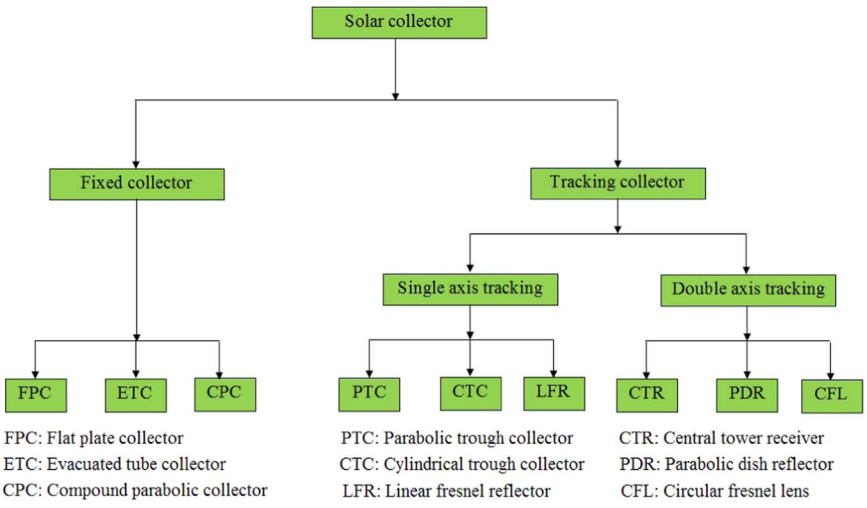

Fig. 1. Types of solar collector.