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The prediction of photovoltaic module temperature with artificial neural networks

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ABSTRACT

In this study, photovoltaic module temperature has been predicted according to outlet air temperature and solar radiation. For this investigation, photovoltaic module temperatures have been determined in the experimental system for 10, 20, 30, and 40 °C ambient air temperature and different solar radiations. This experimental study was made in open air and solar radiation was measured and then this measured data was used for the training of ANN. Photovoltaic module temperatures have been predicted according to solar radiation and outside air temperature for the Aegean region in Turkey. Electrical efficiency and power was also calculated depending on the predicted module temperature. Kütahya, Uşak and Afyon are the most suitable cities in terms of electrical efficiency and power product in the Aegean region in Turkey.

1. Introduction

The solar panels used in photovoltaic systems can be categorized into three groups. These are polycrystalline solar panels, monocrystalline solar panels and amorphous crystal solar panels. Since the production of polycrystalline solar panels commercially is relatively easier, they are the most preferred panels. In addition, they are much cheaper. The efficiency of these three types of solar panels varies from 10% to 20%. Even though the efficiency of polycrystalline solar panels varies in different sources, their efficiency is 15% at the laboratory scale. The efficiency in application could be reduced up to 10%. The biggest loss at solar panels occurs in heating; since it could convert 50% of the solar radiation reflected on it into thermal energy. So it makes solar panels possible to be used in the production of thermal energy. The ANN has been used for predicting different factors of photovoltaic systems. Some of these are listed as below.

Kalogirou et al. [1] used artificial neural networks for the performance prediction of large solar systems. The ANN method is used to predict the expected daily energy output for typical operating conditions, as well as the temperature level of the storage tank can be achieved by the end of the daily operation cycle. Rai et al. [2] developed the simulation model of an ANN based maximum power point tracking controller. The controller consists of an ANN tracker and the optimal control unit. The ANN tracker estimates the voltages and currents corresponding to a maximum power delivered by solar photovoltaic array for variable cell temperature and solar radiation. Karamirad et al. [3] used ANN for predicting photovoltaic panel behaviors under realistic weather conditions. ANN results are compared with analytical four and five

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Nomenclature

d_k	result expected from layer 2
d_o	error occurred at layer 2
d_y	error occurred at layer 1
E	square error occurred in one cycle
$f(net_i)$	activation function
AE	average error
n	data number
net_i	calculation result of layer 1
net_k	calculation result of layer 2
o_k	result of layer 2
R^2	coefficient of correlation
x_i	input data
w_{ij}	weights in layer 1
w_{jk}	weights in layer 2
y_i	results obtained from layer 1
β	term of momentum
ε	coefficient of approximation
Δw_{jk}	correction made in weights at the previous calculation
Δw_{ij}	correction made in weights at the previous calculation
A	area, m^2
$I(t)$	incident solar intensity, W/m^2
T	temperature, °C
P	power, W

Subscript

c	solar cell
g	glass
m	module
α	absorptivity
δ	packing factor
τ	transmittivity

parameter models of the PV module. Ammar et al. [4] suggested a PV/T control algorithm based on ANN to detect the optimal power operating point (OPOP) by considering PV/T model behavior. The OPOP computes the optimum mass flow rate of PV/T for a considered irradiation and ambient temperature. Mellit et al. [5] described a methodology to estimate the profile of the produced power of a 50 Wp Si-polycrystalline photovoltaic module. For this purpose, two ANNs have been developed for use on cloudy and sunny days. Fernandez et al. [6] proposed a model based on ANNs to predict the maximum power of a High Concentrator Photovoltaic (HCPV) module using easily measurable atmospheric parameters. Almonacid et al. [7] characterized Si-crystalline PV modules by ANNs. An ANN has been developed which can generate *V–I* curves of Si-crystalline PV modules for any irradiance and module cell temperature.

In this study, the module temperature has been predicted to be different from the literature. The main factors determining the module temperature is the ambient air temperature and solar radiation. Module temperatures have been determined in the experimental system for the 10, 20, 30, and 40 °C ambient air temperature and different solar radiations. The experimental study was made in open air and solar radiation was measured and then this measured data was used for the training of ANN. The photovoltaic ambient air temperature is controlled in the experimental system and solar radiation in open air is measured. The module temperature was predicted by ANN depending on the outside temperature and solar radiation for the Aegean region of Turkey.

2. Artificial neural networks

Artificial neural networks (ANNs) are good for some tasks, while lacking in some others. Specifically, they are good for tasks involving incomplete-data sets, fuzzy or incomplete information, and for highly complex and ill-defined problems, where humans usually decide on an intuitional basis. They can learn from examples, and are able to deal with non-linear problems. Furthermore, they exhibit robustness and fault-tolerance. The tasks that ANNs cannot handle effectively are those requiring high accuracy and precision, as in logic and arithmetic [8].

The ANNs are widely used in various fields of mathematics, engineering, meteorology, economics and in adaptive control and robotics, in electrical and thermal load predictions and many other subjects [9]. ANNs show structural and mathematical variations. Structural differences arise from the number of layers and the variations of the connections among the nodes. Generally they have three layers as follows: input layer, hidden layer, and output layer. Number of the layers can change and can be rebounded between the layers. This completely depends on the usage purpose of the network and the design of the designer. Number of nodes in the input layer is equal to the number of data given to ANN. Number of nodes at the output layer is equal to the number of knowledge that will be taken from ANN. Node number of the hidden layer is found experimentally. Learning capability of ANN improves as the number of nodes and the connections increase; however, it takes more time to train ANN. A node has many inputs whereas it has only one output. Nodes process these input data and feeds forward to the next layer. Input data are processed as follows: each data was added up after it was multiplied by its weight and then it was subjected to activation function. Thus the data which will be transferred to the next layer is obtained [10].

The algorithm used in training ANN and the type of activation function used at the output of the node are the mathematical differences. Activation functions involve exponential functions and thus non-linear modeling can be achieved.