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ESTIMATION OF THE SOLAR RADIATION MODEL USING MEASURED DATA OF OSMANİYE, TURKEY

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Abstract. *Nowadays, the use of solar radiation is very important for some applications. Knowledge of global solar radiation distribution is needed for the design of solar energy systems for these applications. Many parameters affect the production of solar energy and conversion efficiencies and location conditions of PV panels. One of the most vital parameters is the number of solar radiation values. The main objective of this study is to determine the predicting solar radiation by using meteorological measurements. In this study, two empirical models (linear and second-order polynomial equation) were analyzed according to correlation coefficients for a month for the global solar radiation on horizontal surface in Osmaniye and a new quadratic model has been developed for Osmaniye.*

Key words**:** *Solar radiation, PV, Osmaniye, Empirical models*

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1. Introduction

Recently, renewable energy has been dramatically used in the world, because fossil fuels, such as coal, petroleum and natural gas, are their finite sources and have negative effects on the environment. In this concept, renewable energy plays an important alternative role in replacing fossil fuels. Energy supply from and demand for renewable sources (such as solar or wind) in many countries (both developed and developing) are considered by most of researchers and experts as the current and future task to obtain sustainability of world's energy systems. Moreover, governments in these countries have evaluated the terms of different policies and strategies for investments in renewable energy generation.

One of the important renewable energy sources is solar energy because of its availability in the most parts of the world. Solar energy techniques may use different forms of power generation, such as heating/cooling generation, combined power and heat/cooling generation, and passive systems. It is useful to know the amount of solar energy used in such places. The quantities of solar energy are measured.

Solar energy consists of two parts – extraterrestrial solar energy, which is above the atmosphere, and global solar energy, which is under the atmosphere. The global solar energy incident on a horizontal surface may have a direct beam and diffuse radiation. Diffuse radiation is usually measured by pyranometers and solarimeters. These measuring devices are usually installed at selected sites in a specific region and it is not feasible to install them at many sites due to the high cost of these devices [1].

In spite of the importance of solar radiation measurements, this information is not readily available due to the cost, maintenance and calibration requirements of the measuring equipment. The limited coverage of radiation values dictates the need to develop models to estimate solar radiation [2].

Many solar energy models have been presented in the literature using mathematical linear [3, 4] and nonlinear functions [5, 6], artificial neural network [7, 8] and fuzzy logic [9].

These models give a correlation between the solar energy on a horizontal surface and some meteorological variables, such as sunshine duration, ambient temperature and relative humidity. The linear models use the simple linear function, while the nonlinear models use the polynomial function of the third or fourth degree [1].

In this study, prediction of models for solar radiation in Osmaniye has been investigated by the meteorological measurement device (vantage PRO2). Two empirical models (linear and second-order polynomial equation) are analyzed according to correlation coefficients for a month, for the global solar radiation on horizontal surface in Osmaniye and a new model has been developed. Besides, in order to perform the analysis of the models, the statistical testing methods, such as mean absolute percentage errors (MAPE), mean absolute bias error (MABE), root mean square error (RMSE), were used.

2. Materials and methods

Osmaniye province is located in the eastern Mediterranean region in Turkey, and its coordinates

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are 37.05 north latitude and 36.14 east longitude. Osmaniye is at the height of 120 m above the average sea level and the distance from the Mediterranean Sea is about 20 km. Experimental data for Osmaniye were measured with the meteorological measuring device which is called Vantage Pro2 Weather Station, located in the university campus of Osmaniye Korkut Ata, and the experimental set-up was located at the Department of Energy Systems Engineering. The meteorological measuring device was positioned at the height of 20 m from the ground level, shown in Figure 1, and it measured the actual global solar radiation data on the horizontal surface of Osmaniye in a five-minute time interval for one year. It measured the temperature, humidity, pressure, wind direction and speed, solar radiation, rains. Its resolution and range are 1 W/m², 0 to 1800 W/m², respectively, and nominal accuracy is 5% of full scale. An empirical model correlates solar radiation with other easily measurable parameters, such as sunshine duration, temperature and humidity, by applying concise mathematical functions. Due to its simplicity and strong operability, the empirical model is much more convenient for engineering applications [10].

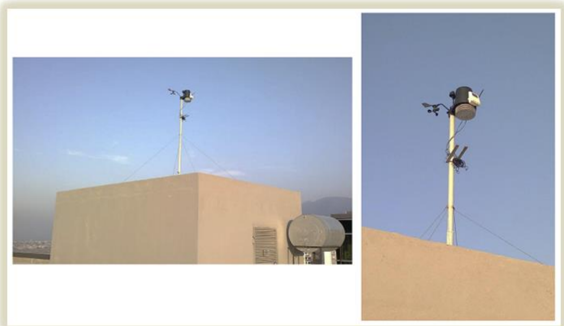

Figure 1. The meteorological measuring device

The first Sunshine duration model was proposed by Angstrom [11], which related the clear sky index with the sunshine duration fraction by using the linear equation. Some researchers have done a large number of modifications on these models to improve the accuracy [12]. These models are given in Table 1.

Table 1. The comparison of different regression models for monthly average daily radiation

Models	Reference
$\frac{H}{H_o} = a + b\frac{S}{S_o}$	Linear [11]
$\frac{H}{H_o} = a + b\frac{S}{S_o} + c(\frac{S}{S_o})^2$	Quadratic [12]
$\frac{H}{H_o} = a + b\frac{S}{S_o} + c(\frac{S}{S_o})^2 + d(\frac{S}{S_o})^3$	Cubic [13]
$\frac{H}{H_o} = a + b\frac{S}{S_o} + c\,log(\frac{S}{S_o})$	Logarithmic [14]
$\frac{H}{H_o} = a(\frac{S}{S_o})^b$	Exponent [15]

where H is the monthly average daily global radiation, H_o is the extraterrestrial radiation, S is the monthly average sunshine duration, S_o is the monthly average of the maximum possible sunshine duration, a, b, c and d are empirical constants.

The performance of an established solar radiation model is evaluated in terms of the root mean square error (RMSE), the mean absolute percentage error (MAPE) and the mean absolute bias error (MABE). These error terms can be obtained using the following equations:

$$MAPE = \frac{1}{x}\sum_{i=1}^{x}\left|\frac{H_{i,c} - H_{i,m}}{H_{i,m}}\right| X100 \quad (1)$$

$$MABE = \frac{1}{x}\sum_{i=1}^{x}\left|H_{i,c} - H_{i,m}\right| \quad (2)$$

$$RMSE = \sqrt{\frac{1}{x}\sum_{i=1}^{x}\left(H_{i,c} - H_{i,m}\right)^2} \quad (3)$$

where $H_{i,c}$ and $H_{i,m}$ are the i-th calculated and measured values, respectively, and x is the total number of observations.

3. Results and discussion

Although it is not possible to estimate the daily total amount of global solar radiation on a particular day from sunshine duration using this method, it does enable an estimation of a monthly value. In this study, the experimental data of monthly average global solar radiation were calculated for Osmaniye province.

The authors described a second order polynomial regression between the measured daily values of $H=H_o$ and $S=S_o$ for a month (June) in the province of Osmaniye [16]:

$$\frac{H}{H_o} = -0.149 + 0.960\frac{S}{S_o} \quad (4)$$

$$\frac{H}{H_o} = -0.351 + 1.488\frac{S}{S_o} - 0.343\left(\frac{S}{S_o}\right)^2 \quad (5)$$

Akinoglu and Ecevit obtained a second order polynomial equation for Turkey [17], the correlation is given in Eq. 6 between (H/H_o) and (S/S_o):

$$\frac{H}{H_o} = 0.145 + 0.845\frac{S}{S_o} - 0.280\left(\frac{S}{S_o}\right)^2 \quad (6)$$

Moreover, the average quadratic equation of the model (Eq. 7) was written by Aktağ and Yılmaz [18]:

$$\frac{H}{H_o} = 0.071 + 1.197\frac{S}{S_o} - 0.724\left(\frac{S}{S_o}\right)^2 \quad (7)$$

The values of MABE, MAPE and RMSE for each model are shown in Table 2. As a result of linear, second order polynomial regression analysis, the best model is the second order polynomial model. Quadratic has the smallest errors than the others and it is found to be the most accurate model.

Table 2. The summary of all statistical parameters for Linear and Quadratic

Models	RMSE	MAPE	MABE	R^2
Linear	0.398	11.668	0.456	0.868
Quadratic	0.397	6.663	0.455	0.867

4. CONCLUSIONS

Solar radiation data are important for the design and study of solar energy. Empirical correlations estimated the monthly average daily global radiation. In this study, solar radiation models on the horizontal surface have been investigated experimentally and compared with 2 models. As a result of the measured data, with the aim of determining the solar energy potential in Osmaniye, a new model has been developed and two different models have been compared with each other by using the radiation data previously obtained. In order to evaluate the performance of these models, different statistical indicators, such as the mean absolute percentage errors (MAPE), the mean absolute bias error (MABE) and the root mean square error (RMSE), were examined. A new two-order polynomial monthly model was developed and found to be the most accurate according to MABE, MAPE and RMSE. It also has the best performance considering the measured data at the station in Osmaniye. The results reveal that a new model seems to be highly acceptable for predicting solar radiation.

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