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SOLAR ENERGY POTENTIAL IN MERSIN AND A SIMLE MODEL TO PREDICT DAILY SOLAR RADIATION

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Abstract

In this study, solar energy potential of Mersin which is placed in Mediterranean region of Turkey was investigated by using meteorological data of Turkish State Meteorological Service and meteorological satellite (HelioClim©). A simple model to predict solar radiation was developed and compared with the other models published in literature. Proposed model estimated daily global solar radiation by using difference of maximum and minimum temperatures. Daily and monthly solar radiation data was estimated with 14.7% and 9.1% absolute mean percentage error, respectively.
Keywords: Mersin, Turkey, Solar radiation model, Daily and monthly solar radiation

MERSİN İLİNİN GÜNEŞ ENERJİ POTANSİYELİ VE BASİT BİR GÜNEŞ IŞINIM MODELİ

Özet

Bu çalışma kapsamında Türkiye'nin Akdeniz bölgesinde yer alan Mersin ilinin güneş enerji potansiyeli Devlet Meteoroloji İşleri (DMİ) Genel Müdürlüğünden ve HelioClim© veri tabanından elde edilen bilgiler kullanılarak incelenmiştir. Günlük en yüksek ve en düşük sıcaklık değerlerine göre günlük güneş ışınımını tahmin etmek için basit bir model geliştirilmiş ve literatürde yer alan diğer modeller ile karşılaştırılmıştır. Bu model günlük ışınım miktarını %14,7, aylık toplam ışınım miktarını ise %9,1 hata ile hesaplamıştır.
Anahtar Kelimeler: Mersin, Türkiye, Güneş ışınım modeli, Günlük ve aylık global güneş ışınımı

1 Introduction

Depletion of fossil fuel sources and increase in energy demand urge scientist and engineers to focus their studies on renewable energy sources. Solar, wind, geothermal and wave energies are the main renewable energy resources. Solar energy has the highest potential among those resources. Current technology allows humankind to use solar energy potential by converting it to process heat or converting directly to electric energy by using photovoltaic panels. Another advantage of solar energy is the homogeneous distribution all over the world. Based on those facts, engineers should estimate solar radiation flux accurately to design systems properly.

Global solar radiation reaching the earth's surface depends upon so many parameters. Almorox [1] sorted those parameters as astronomical factors (solar constant, world-sun distance, solar declination and hour angle); geographical factors (latitude, longitude and altitude); geometrical factors (surface azimuth, surface tilt angle, solar altitude, solar azimuth); physical factors (albedo, scattering of air molecules, water vapor content, scattering of dust and other atmospheric constituents); and meteorological factors (atmospheric pressure, cloudiness, temperature and sunshine duration, air temperature, soil temperature, relative humidity, evaporation, precipitation number of rainy days, etc.). Solar radiation models are developed by using some of those parameters.

2 Review of Solar Radiation Models

Most common used models to estimate global solar radiation on a horizontal surface use Angström-Prescott type models which are derived according to sunshine duration time on given in Equation (1).

$$\frac{Q_{model}}{Q_0} = a + b\frac{t}{t_0} \qquad (1)$$

The constants *a* and *b* may differ according to the location of the region where solar radiation is going to be estimated. Kılıç and Öztürk [2] correlated those constants given in Equation (2) by using the latitude, elevation and declination angle of different regions of Turkey.

$$a = 0.103 + 0.000017z + 0.198\cos(e - d)$$
$$b = 0.533 - 0.165\cos(e - d) \qquad (2)$$

Bulut and Büyükalaca [3] correlated solar radiation data measured by Turkish State Meteorological Service at different regions of Turkey. Correlation estimates daily total radiation on horizontal surface only by using day number as given in Equation (3).

$$Q_{model} = a + (b - a)\left|sin\left(\frac{\pi}{365}(n + 5)\right)\right|^{1.5} \qquad (3)$$

The constants a and b are given as 7.01 and 25 for Mersin, respectively.

Some meteorological factors such as cloudiness and sunshine duration don't measured in all meteorological stations. For that reason, researchers developed solar radiation models by using meteorological factors which are measured all stations such as dry-bulb temperature, wind speed, etc. Hargreaves and Samani [4] correlated daily total radiation on horizontal surface according to difference of daily maximum and minimum temperatures on given in Equation (4).

$$Q_{model} = Q_0\left[0.1459(T_{max} - T_{min})^{1/2}\right] \quad (4)$$

Zhang and Huang [5] developed a solar radiation model which is valid for China to predict hourly total radiation on horizontal surface. This model was correlated according to the typical meteorological year data. Cloudiness (cloud cover), dry-bulb temperature, relative humidity and wind speed were used to estimate the solar radiation.

$$I_{model} = [I_0 sin(h)\{c_0 + c_1 CC + c_2 CC^2 + c_3(T_i - T_{i-3}) + c_4 RH + c_5 V_r\} + d]/k \quad (5)$$

The constants in Equation (5) were given as c_0=37.6865, c_1=13.9263, c_2=-20.2354, c_3=0.9695, c_4=-0.2046, c_5=-0.098, d=-10.8568, k=49.3112. Al-Anzi et.al. [6] modified this model according to the meteorological data of Kuwait. Regression coefficients were given as c_0=0.4398, c_1=0.6082, c_2=-0.5762, c_3=0.0144, c_4=-0.0012, c_5=0.014, d=-50.15, k=0.843.

3 Solar Energy Potential in Mersin

Meteorological data used in this study is obtained from Meteonorm© and HelioClim© databases. Meteonorm© database includes meteorological weather stations data measured by Turkish State Meteorological Service. To analyze solar energy potential, data measured in the weather station (latitude=34.6°, longitude=36.817°, elevation=10 m) in Mersin is used. HelioClim© database is formed by processing meteorological satellite images.

In Fig. 1, monthly total radiation on horizontal surface obtained from databases is given.

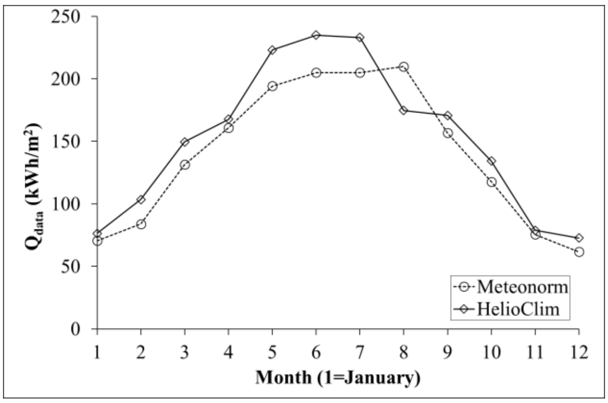

Figure 1. Monthly total global solar radiation .

Solar radiation data of Meteonorm© database is always lower than the HelioClim© database except eighth month (August). In autumn and winter seasons the difference between two databases is lower than 20%. In spring and summer seasons this difference lower than 12%. Each databases has distinctive uncertainties and to minimize the error characteristic solar radiation data is obtained by averaging these two databases.

In Fig. 2, daily solar radiation on horizontal surface of the characteristic data is given. Yearly total radiation in measured 1750 kWh m^{-2}. Lowest monthly radiation is 67 kWh m^{-2} in December and highest monthly radiation is obtained 220 kWh m^{-2} in June-July. Highest and lowest daily solar radiation are obtained 8.35 kWh m^{-2} 0.95 kWh m^{-2}, respectively.

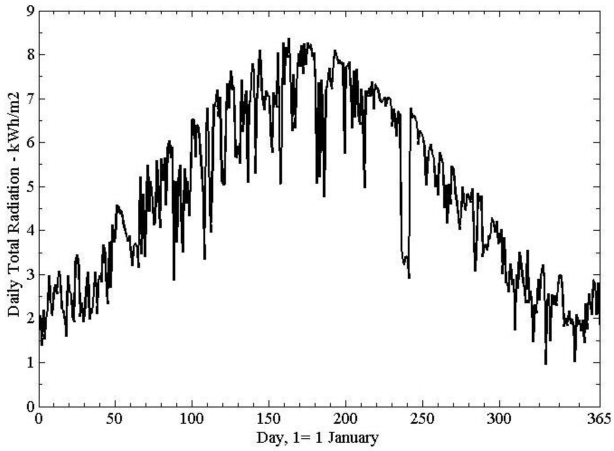

Figure 2. Daily solar radiation on horizontal surface of the characteristic data

4 Comparison of Solar Radiation Models with Characteristic Data

Characteristic solar radiation data is compared with the models: Kılıç and Öztürk [2] (model 1), Bulut ve Büyükalaca [3] (model 2), Hargreaves and Samani [4] (model 3), Zhang and Huang [5] (model 4) and Al-Anzi et.al [6] (model 5). The success of the models to predict solar radiation data is determined according to mean absolute percentage error as given in Equation 6.

$$\varepsilon = \frac{100}{n}\sum\left|\frac{Q_{data} - Q_{model}}{Q_{data}}\right| \quad (6)$$

Solar radiation models were correlated by using long time measured meteorological data. Model 1 and Model 2 used local meteorological data to determine regression coefficients. However model 3, 4 and 5 were developed according to foreign countries meteorological data. In Table 1, the success of each model to predict daily and monthly total solar radiation data is given with mean absolute percentage error.

Table 1. The success of the models to determine the amount of daily solar radiation.

Model No	ε_{daily} (%)	$\varepsilon_{monthly}$ (%)
1. Kılıç and Öztürk [2]	25	6
2. Bulut and Büyükalaca [3]	16	3
3. Hargreaves and Samani [4]	22	18
4. Zhang and Huang [5]	71	71
5. Al-Anzi and etc. [6]	56	54
6. Current study	14.7	9.1

In daily error analysis, most successful result is obtained from model 2. The main reason of the model success is that regression coefficients were determined only using Mersin meteorological data. However, this model is only function of a day number. Despite model 3 used only daily outdoor temperature derived for another region, it is the second successful model to estimate daily solar radiation in Mersin.

Model 4 and 5 are the same type models with different regression coefficients. First one is valid for China and second one is for Kuwait. Both of the countries are in different climate zone with Mersin. Moreover, these models used four different meteorological parameters. Those are the main reasons of the failure of the model 4 and 5 to predict solar radiation data.

In solar radiation analysis, monthly radiation data may be used in engineering applications. In Table 1, error analysis of solar radiation data which is summation of daily data is also given.

Each model increased the success of predicting solar radiation when compared with daily analysis. Especially, remarkable improvement is observed in model 1 predictions. The main reason of this improvement is the uniform scattering of overestimated and underestimated predicted data.

5 Estimation of Daily Total Solar Radiation Based on Meteorological Data

In Daily and monthly analysis, model 3 predicts the solar radiation data of Mersin with 22% and %18 error, respectively. This simple model regression coefficient is developed based on other foreign countries and in this study, new coefficients are developed based on local meteorological data. In Fig. 3, the correlative relation between the Daily difference of maximum and minimum temperatures with solar radiation data is given.

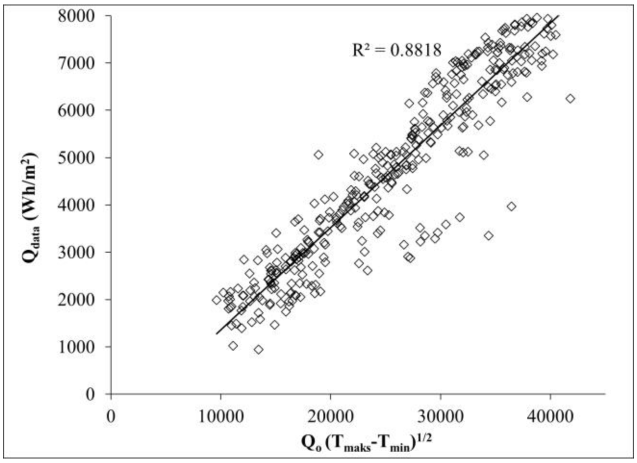

Figure 3. The correlative relation between the temperature differences with solar radiation data

A strong linear relation is determined. According to that, new coefficient is determined by regression analysis and proposed model in give in Equation 7.

$$Q_{model} = Q_0\left[0.182(T_{max} - T_{min})^{1/2}\right] \quad (7)$$

In Fig. 4, deviation of daily predicted data is given. Proposed model predicts daily and monthly total solar radiation data of Mersin with an absolute mean error of 14.7% and 9.1%, respectively.

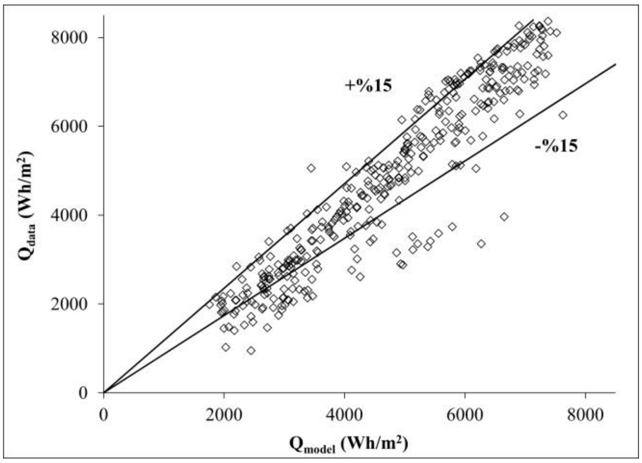

Figure 4: Comparison of the proposed new model with database results

At high solar radiation level, the proposed model success is increasing. Especially, in autumn and winter season, other meteorological parameters different from outdoor dry-bulb temperature are more effective. For that reason, deviation of the proposed model increased at low solar radiation level.

6 Conclusion

In this study, solar energy potential of Mersin was discussed in detail according to the meteorological data of Turkish State Meteorological Service and meteorological satellite (HelioClim©) database. Solar radiation models which are formed with different parameters were compared with characteristic data. The most successful result was obtained from model 2 since this model is developed by using regional meteorology data. However, the only parameter is day number. Different from this model, model 1 is formed by using sunshine duration. This model is not successful as model 2 to predict Daily solar radiation but positive results are obtained in monthly analysis. Model 3, 4 and 5 are developed for foreign countries. Among those model, model 3 is the most successful one. To improve this model, coefficients are revised according to the local data. Proposed model predicts Daily and monthly solar radiation data with an absolute mean error of 14.7 % and 9.1 %, respectively.

7 References

[1] Almorox J., ‘‘Estimating Global Solar Radiation From Common Meteorological Data in Arajuez’’, Spain, Turk. J. Phys., 35, 53-64, 2011.

[2] Kılıç, A. and Öztürk, A., ‘‘Güneş Enerjisi’’, Kipaş Dağıtımcılık, İstanbul, 1983.

[3] Bulut H. and Büyükalaca O., ‘‘Simple Model For The Generation of Daily Global Solar-Radiation Data in Turkey’’, Applied Energy, 84, 477-491, 2007.

[4] Hargreaves G. H. and Samani Z. A., ‘‘Estimation of Potential Evapotranspiration’’, Journal of Irrigation and Drainage Division, Proceedings of the American Society of Civil Engineers, 108, 223-230, 1982.

[5] Zhang Q. Y. and Huang Y. J., ‘‘Development of Typical Year Weather Files for Chinese Locations’’, ASHRAE Transactions, 108, 1063-1075, 2002.

[6] Al-Anzi A., Seo D. and Krarti M., ''Impact of Solar Model Selection on Building Energy Analysis for Kuwait'', Journal of Solar Energy Engineering, 130, 0210041-6, 2008.

Nomenclature

CC	Cloud cover
d	Declination angle (degrees)
e	Latitude (degrees)
h	Solar altitude angle (degrees)
I_{model}	Predicted hourly total radiation on horizontal surface (Wh m^{-2})
n	Number of day, starting from the first of January
Q_{model}	Predicted daily total radiation on horizontal surface (Wh m^{-2})
Q_0	Extraterrestrial solar radiation (Wh m^{-2})
Q_{data}	Daily total radiation on horizontal surface based on metrological data (Wh m^{-2})
RH	Relative humidity (%)
T	Dry-bulb temperature (°C)
T_i	Dry-bulb temperature at hour ''i'', current time (°C)
T_{i-3}	Dry-bulb temperature at hour ''i-3'', current time (°C)
t	Sunshine duration (hour)
t_o	Day length (hour)
V_r	Wind speed (m s^{-1})
z	Elevation (m)
ε	Mean absolute percentage error (%)