Modelling of global solar radiation in Algeria based on geographical and all climatic parameters

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Abstract The design of photovoltaic or solar systems and estimating their performance require knowledge of the intensity of solar radiation. The measurement of this parameter for some sites in Algeria is unfortunately not obvious. However, researchers are moving towards the modeling, estimation and prediction. To model the global solar radiation in Algeria, we must take into account the geographical and climatical parameters such as sunshine duration, relative humidity, temperature, latitude site, etc... In this study, the modeling of daily global solar radiation on a horizontal plane according to the parameters mentioned above, is based on the statistical linear regression technique. The daily data used in the development and validation of models are extracted from the database of O. N. M (National Office of Meteorology, Dar el Beida. Algiers) for 2001-2005. We test the proposed models on two sites with their geographical and climatical parameters are different such as Djelfa and Ain Bessam. For each site, validity and performance of the model will be studied based on the number of parameters introduced in the analytical expressions and results are discussed in terms of statistical errors as: R, MBE and RMSE between the measured global solar radiation and global solar radiation estimated. It was found that air temperature and relative humidity are indeed important climatic parameters for the prediction of solar radiation.
Keywords: global solar radiation, modeling, statistical regression, geographical, climatic parameters.

I. INTRODUCTION

Solar energy is the most ancient source of energy; it is the basic element for almost all fossil and renewable types. Using solar energy to generate electrical energy for any specific site location necessitates an exact estimation of global solar radiation; a provision should be made to forecast solar energy which will convert to electrical energy to recover the load demand, that is, the amount of solar energy for that place ought to be known. Technology for measuring global solar radiation is costly and has instrumental hazards. The importance of the actual work lies on the fundamental need of quantification of the global solar radiation data in this site.

The solar radiation reaching the earth's surface depends on the climatic condition of the specific site location [11]-[13]. Therefore, over the last decades, different models have been proposed to predict the amount of solar radiation using various parameters. Most analyses of the correlation between solar radiation and climatic parameters involve the use of relative sunshine duration [3], [5], [9], [10]. However, air temperature and humidity should also be considered as an important climatic variable for solar radiation prediction because it is a reflection of both the duration and intensity of the solar radiation incident on a given location [1], [2],[6],[7],[8].

II. DATA

Measured global solar irradiation (G) and climatic parameters data, between 2001 and 2005, for two cities in Algeria: Ain Bessem (Latitude 36.31°N, Longitude 3.67°E, Altitude 629 (m)) and Djelfa (Latitude 34.68°N, Longitude 3.25°E, Altitude 1126 (m)), were obtained from Algerian Meteorological Agency O.N.M, Dar el Beida.

Our aim is to develop a best model with a few climatic parameters to estimate the solar radiation data (G/G0) in future time domain. The estimations were made by many combinations of data, by using a linear regression analysis.

These data are chosen due to their correlation with the global solar radiation. In linear regression model, the dependent variable comprises the ratio of the global solar irradiation (G) to the available radiation at the top of the atmosphere (G0); and the independent variables comprise the different climatic parameters (mean daily maximum temperature, mean daily relative humidity, mean daily sea level pressure, mean daily vapour pressure, wind, precipitation and the ratio of hours of bright sunshine (S) to the day length (S0). The measured data between 2001 and 2004 have been used for calculating the coefficients of the model while those from 2005 are used for testing data. The testing data are not used in modelling.

The values of the extraterrestrial radiation G0 and the day length S0 were calculated. The data was subjected to quality checks before being used in the analysis. It was ensured only complete data set was used. The values of G/Go and S/So are all less than one.

III. DISCUSSION

The choice of a number of models is conducted by the fact that the single model does not give a good generalization for the sites under study. Accordingly, several models have been tested to choose the more suitable for each location. Statistical analysis of the results was performed using the correlation coefficient (R), the root mean square error (RMSE) and the mean bias error (MBE) criteria [4, 8].

	P	V	R	Tx	Tm	Tn	Um	S/S0	T/Tx	U/U x	$(Tn/Tx)^2$
Ain Bessem	0.644	0.307	-0.329	0.723	0 .66 1	0.546	-0.114	0.454	-0.068	-0.636	-0 .237
Djelfa	0.215	0.012	-0.272	0.505	0.450	0.343	-0.591	0.293	0.316	-0.534	0.199

Table 1: Pearson's correlation coefficients

The study of correlations among solar radiation and several climatic parameters has shown that (S/So) is not the best single parameter to be used for predicting solar radiation. For example, Table 1 below shows Pearson's correlation coefficients for Ain Bessem and Djelfa cities. It is seen that for Ain Bessem, (G/Go) correlate best with (Tx), followed by Tm and S/So, respectively, while (Um) and (Tx) are best followed by Tm for Djelfa. Thus in both cases, the best single parameter for estimating (G/Go) is not (S/So).

Models	Ain Bessem
1	G/G0 = 0.2597 + 0.103 (Tx)
2	G/G0 = 0.142 + 0.069 (Tx) -0.075 (Tm)
3	G/G0 = 0.1621 + 0.0352 (Tx) -0.0418 (Tn)
4	G/G0 = 0.152 + 0.046 (Tx) -0.021 (Tm) – 0.031(Tn)
5	G/G0 =0.4365 +0.0305 (Tx) -0.0312 (Tn) -0.3924(Tm/Tx)
6	G/G0 = 0.7152 +0.077 (Tx) – 0.0294 (Tn) – 0.4701 (Tm/Tx) -0.2372(Um/Ux)
7	G/G0 = 0.6740 +0.0238 (Tx)- 0.0266 (Tn) -0.3743 (Tm/Tx) -0.3503 (Um/Ux) + 0.0001(P)
8	G/G0 = 0. 6855 +0.0219 (Tx) – 0.0244 (Tn) -0. 3357 (Tm/Tx) - 0. 4033 (Um/Ux) + 0002(P) -0.0051 (Vx)
9	G/G0 = 0.6731 + 0.0216 (Tx) – 0.0242 (Tn) – 0.3326 (Tm/Tx) - 0.3851 (Um/Ux) + 0.0002 (P) – 0.0042 (Vx) -0.0034 (R)
10	G/G0 =0.5707+ 0.0004 (P) - 0.0046 (Vx) - 0.0028 (R) + 0.0257 (Tx) - 0.0202 (Tn) - 0.0116 (Tm) - 0.2817(Tm/Tx)- 0.2905(Um/Ux) - 0.0026 (Um)

Table 2: Models used for estimating (G/G0) for Ain-Bessem city

Model	R	TEST Ain Bessem (2005)		
		R	RMSE	MBE
1	0.7230	0.352520927	0.01852614	0.225915
3	0.8880	0.211123077	0.00735662	0.002873
5	0.8930	0.938316204	0.04267256	-0.173248
6	0.8980	0.509463204	0.09311018	-1.245345
7	0.9030	0.951980262	0.03279929	-0.034701
8	0.9070	0.939969203	0.02980376	-0.042758
9	0.9090	0.937548948	0.02951324	-0.048033
10	0.9110	0.939948903	0.02980376	-0.042758

Table 3: Statistical analysis of the results. The correlation coefficient (R), the root mean square error (RMSE) and the mean bias error (MBE)

From Table 3, we can observe that the correlation coefficient for the studied models, listed presented in Table 2, is arranged between 72.30% and 91.00%. It is clearly shown that, the best performance is obtained by the models (7, 8, 9 and10) where the correlation coefficient R is arranged between 90.30% and 91.10%. However, the best correlation in test is obtained for the model 7, and this model need in his input only (T, U) parameters and P that are always available, and they can be measure easily. The obtained R is 95.20%, which is higher than other models. The RMSE is 0.032799 and the MBE is -0.034701. Fig.1 shows a comparison between measured and estimated daily global solar radiation by using model 7.

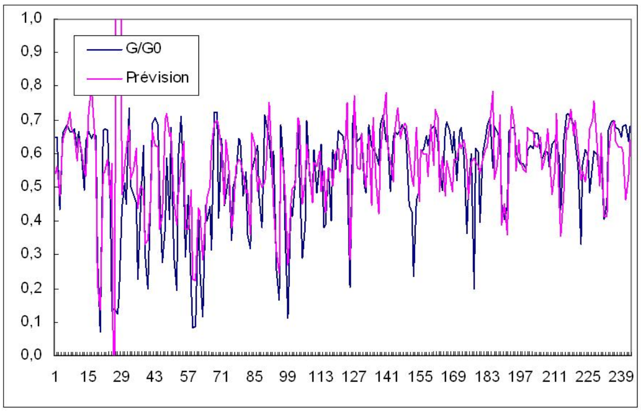

Fig.1 shows a comparison between measured and estimated daily global solar radiation by using model 7 (Ain Bessem).

In addition, we have developed others models for Djelfa city, where the relative humidity is always combined with temperature. Therefore, we develop these models in order to show the influence of each parameter for estimating daily global solar radiation.

Model	R	Djelfa
1	0.591	$G/G0 = 0.8670 - 0.0037\,(Um)$
2	0.691	$G/G0 = 1.0761 - 0.0062(Um) - 0.4876(Tn/((Tx))2$
3	0.711	$G/G0 = 1.1558 - 0.0067(Um) - 0.5361(Tn/(Tx))^2 - 0.0058(Vx)$
4	0.719	$G/G0 = 0.9216 - 0.0044(Um) - 0.6990(Tn/(Tx))2 - 0.0050(Vx) + 0.0060(Tx)$
5	0.729	$G/G0 = 0.8608 - 0.0036(Um) - 0.6986(Tn/(Tx))2 - 0.0043(Vx) + 0.0070(Tx) - 0.0090(R)$
6	0.735	$G/G0 = 0.8542 - 0.0038(Um) - 0.6833(Tn/(Tx))^2 - 0.0055(Vx) + 0.0096(Tx) - 0.0091(R) - 0.0002(Tx^2\,(Um/Ux)^2)$
7	0.766	$G/G0 = 0.7009 - 0.0029(Um) - 0.6843(Tn/(Tx))2 - 0.0056(Vx) - 0.0051(Tx) - 0.0094(R) - 0.0011(Tx2(Um/Ux)2) + 0.0367(Tx(S/S0))$
8	0.777	$G/G0 = 1.3177 - 0.0031(Um) - 0.7299(Tn/(Tx))^2 - 0.0048(Vx) - 0.0465(Tx) - 0.0099(R) - 0.0019(Tx^2\,(Um/Ux)^2) + 0.1077(Tx)(S/S0) - 0.9871(S/S0)$
9	0.794	$G/G0 = 1.9491 - 0.0032(Um) - 0.7658(Tn/(Tx))^2 - 0.0026(Vx) - 0.0400(Tx) - 0.0102(R) - 0.0018(Tx^2\,(Um/Ux)^2) + 0.0983(Tx(S/S0)) - 2.3323(S/S0) + 1.1687(Um/Ux)^2$
10	0.802	$G/G0 = -2.3357 - 0.0040(Um) - 0.7222(Tn/(Tx))^2 - 0.0019(Vx) - 0.0506(Tx) - 0.0087(R) - 0.0020(Tx^2(Um/Ux)^2) + 0.1139(Tx(S/S0)) - 2.6457(S/S0) + 1.2358(Um/Ux)^2 + 0.0051(P)$
11	0.791	$G/G0 = -3.099 - 0.004\,(Um) + 0.049\,(Tm) + 0.085\,((Tn/Tx)^2)\,0.004\,(P) - 0.003\,(Vx) - 0.010\,(R) + 0.612\,(Tm/Tx) + 0.059\,(Um/Ux) - 0.001\,(Tx(Um/Ux)^2) - 0.126\,(Tn/Tx) - 0.015\,(Tx(Um/Ux)) - 0.015\,(Tn) + 0.049\,(Tx)$

Table 4: Models used for estimating for Djelfa city

Table 4 resumes the different models used for estimating (G/G0) for Djelfa city. Therefore, in the case, when we use as input only the relative humidity and temperature, the best correlation coefficient is decreases to 79.10% (model 11). Also, when we mixed air temperature, relative humidity and the ratio S/S0 the correlation coefficient is decreases only to 80.20% (model 10). Therefore, the model combined (T and U) can be used in the case when we have not the sunshine duration. Fig. shows a comparison between measured and estimated daily global solar radiation by using model 11.

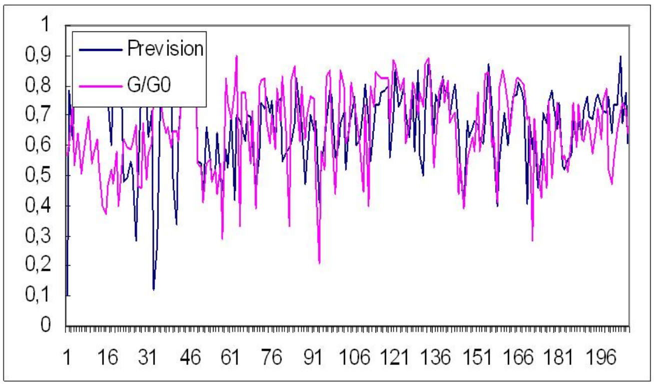

Fig.2 shows a comparison between measured and estimated daily global solar radiation by using model 11 (Djelfa).

It is thus clear that air temperature and relative humidity are indeed important climatic parameters for the prediction of solar radiation.

IV. Conclusion

Using different combinations of different variables to analyse available data for two stations located in different geographical and climatic zones in Algeria, it is clearly demonstrated that air temperature and humidity are an important climatic parameters which should be used in solar radiation modelling in Algeria. The use of only temperature and relative humidity for solar radiation prediction is important because there are many Algerian stations with sufficient data for T and U (which are relatively easier to measure).

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