EXPERIMENTAL COMPARISON OF DIFFERENT GLOBAL IRRADIATION MODELS WITH AND WITHOUT SUN TRACKING FOR THE SOUTH OF SPAIN

Lillo, I; Silva, M; Larrañeta, M.
Escuela Superior de Ingenieros de Sevilla
Avenida de los Descubrimientos, s/n
41092. Seville (SPAIN)
E-mail: isidorolillo@etsi.us.es

ABSTRACT: It is very unusual to have global irradiance data for a tilted surface and even more for a surface with a perfect sun tracking. The most common available data is the global horizontal irradiance, thus it is necessary to convert the available data into the desirable inclination. The purpose of this paper is to analyse the different response of the radiation models that are used to calculate the global irradiance in static surfaces and in surfaces with a perfect sun tracking (two axis). For that end 10 years of measured data has been utilized. The combination of methods that better approaches to the experimental values is the one formed by Orgill - Hollands and Perez for stationary surfaces and mode-Temps-Coulson for two-axis tracking.
Keywords: Solar radiation, Modeling, Photovoltaic

1 INTRODUCTION

In the design of solar systems it is necessary to carry out a preliminary solar resource assessment in order to select a suitable location for the facility. However, having a database of direct and diffuse radiation, of adequate size and quality, is really rare. For this reason, in recent years there have been different estimation models that are able to indirectly calculate the solar radiation and its components [1].

Selecting the right model in each case depends mainly on the input data available; it is very unusual to have global irradiance data for a tilted surface and even more for a surface with a perfect sun tracking. The most common available data is the global horizontal irradiance; in consequence the analysed models are based on this data.

There are two different types of radiation models evaluated in this paper, the first ones (1) calculate the proportion of diffuse irradiance available on a horizontal surface and the second ones (2) calculate the diffuse irradiance available in tilted surfaces. These are the models considered:

1) Orgil – Hollands [2], M. Iqbal [3], Mean, Median y Mode.
2) Circunsolar, Isotropic, Temp – Couson [4], Klucher [5], Hay, Willmott and Pérez [6].

2 OBJECTIVE

The aim of the study is to perform a sensitivity analysis of two radiation models to estimate the solar radiation on inclined surfaces and surfaces with tracking systems on two axes.

To perform the study, it has been used the values measured by The Group of Thermodynamics and Renewable Energies (GTER) of the University of Seville that has been recording radiometric measurements since 1984 at the meteorological station installed at the School of Engineering of the University of Seville and other data measured in Sanlúcar la Mayor (Seville). The data used is: global irradiation on a horizontal surface, global irradiation on inclined surface at 37° facing south and global irradiation on a surface with a two-axis tracking system.

Furthermore, regarding the comparison made for stationary surfaces, the analysis has been also performed with the same data but taken from the Meteonorm database.

3 METHODOLOGY

Two K_t – K_d conversion models has been utilized to calculate the diffuse irradiance in an hourly time step.

K_t – K_d methods are used for the decomposition of global horizontal irradiation into its two components, direct and diffuse. Diffuse methods are used for determining the diffuse irradiance on inclined surfaces from the diffuse irradiance value on horizontal surfaces.

The different methods used are listed below:

K_t – K_d :	**Diffuse:**
Horgill – Holland	Circunsolar
M. Iqbal	Isotropic
Mean	Temps.- Coulson
Median	Klucher
Mode	Hay
	Willmott
	Pérez

The study has been performed for three different scenarios depending on the used database.

3.1. GTER database

The data used are those mentioned in the introduction, measured in the School of Engineering of Seville during the years 2006 and 2012. The collected data has been filtered by different methods to eliminate erroneous measurement. Moreover, given the importance of photovoltaic uptake, we have only considered the hours that irradiance levels exceed 50 W/m^2.

It has been analyzed a total of 20263 hours spread evenly across the five utilized years. Starting from the global horizontal irradiance and using the conversion models, it has been calculated the global inclined irradiance which has been compared with the measured inclined irradiance.

3.2. METEONORM database

In this case, it has been analyzed 8760hours, corresponding to the Typical Meteorological Year based on NREL methodology [7] extracted from the METEONORM database for the site of Seville. The sensitive analysis has been performed in the same way as in the previous case, starting from the global horizontal irradiance and using the conversion models, it has been calculated the global inclined irradiance which has been compared with the measured inclined irradiance.

3.3. Two axes tracking system surface

The data used were recorded in Sanlucar la Mayor (Seville) in 2011. The analyzed values correspond to hourly global irradiation measurements on a horizontal surface and hourly global irradiation data on a surface leaning on a two axes tracking system. Again, the estimated irradiance calculated with teoretical models, is conpared with the measured data.

4 RESULTS

The results of the study are the relative errors in percent that are committed to approximate the experimental values for any of the combinations of the considered radiation methods. Two types of errors have been taken into account regarding to those absolute and signed errors. There are differences between the two errors, because the calculations are performed every year, and the sign is involved into the sum of the annual results.

The relative errors are calculated using the expression 3.1:

$$Error\,(\%)_1 = \frac{|Calculated - Experimental|}{Experimental} \cdot 100 \qquad [3.1]$$

If errors are determined considering the sign, these are calculated by the expression 3.2.

$$Error(\%)_2 = \frac{Calculated - Experimental}{Experimental} \cdot 100 \qquad [3.2]$$

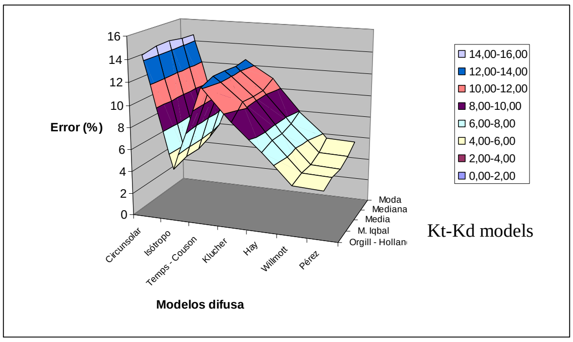
4.1.- GTER database

The results of the study by considering the absolute values are presented in Table I:

Table I: Relative errors calculated on a inclined surfaces with different models

Modelos	Circunsolar	Isótropo	Temps - Coulson	Klucher	Hay	Willmott	Pérez
Orgill - Hollands	14,44	4,71	12,10	9,32	7,03	4,44	4,28
M. Iqbal	14,80	5,09	12,51	10,46	7,31	4,73	4,64
Average	14,84	5,01	12,48	10,37	7,24	4,66	4,55
Median	14,60	5,34	12,35	10,29	7,45	5,01	4,89
Mode	14,60	6,08	12,51	10,87	7,94	5,65	5,50

The results are presented graphically in the next chart:



Graph 1.- Relative errors calculated with GTER data and the equation 3.1.

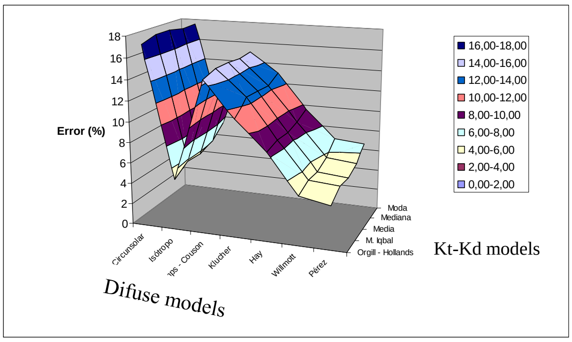
It is observed how the combination of methods that is closer to the experimental values is formed by Orgill - Hollands and Perez.

The results of the study by taking into account the sign (E_C 3.2) are presented in Table II:

Table II: Relative errors taking into account the sign in calculating the value of global adiation on inclined surfaces with different models

Modelos	Circunsolar	Isótropo	Temps - Coulson	Klucher	Hay	Willmott	Pérez
Orgill - Hollands	17,33	4,91	14,53	11,21	8,44	4,73	4,15
M. Iqbal	17,77	5,79	15,02	12,57	8,78	5,27	5,00
Average	17,81	5,66	14,99	12,46	8,70	5,16	4,87
Median	17,53	6,18	14,83	12,36	8,95	5,72	5,40
Mode	17,52	7,31	15,02	13,06	9,54	6,80	6,53

The results are presented graphically in the next chart:



Graph 2.- Relative errors calculated with GTER data and the equation 3.2.

It is observed that the best combination of models is identical to the previous case. Moreover, the results are quite similar, since the use of computational methods overestimates solar radiation values in general.

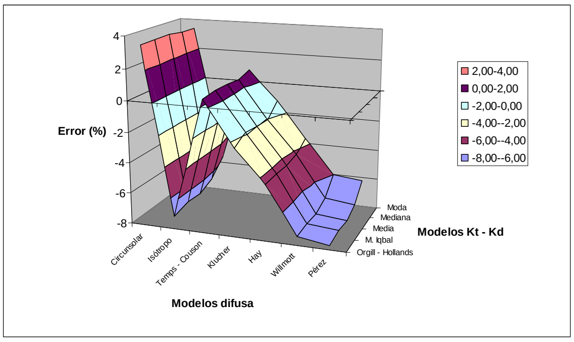
4.2.- METEONORM database

In the case of using METEONORM database, the obtained results are presented in the next table:

Table III: Relative errors taking into account the sign in calculating the value of global adiation on inclined surfaces with different models.

Modelos	Circunsolar	Isótropo	Temps - Coulson	Klucher	Hay	Willmott	Pérez
Orgill - Hollands	3,51	-7,14	0,49	-2,32	-4,37	-7,41	-7,74
M. Iqbal	3,54	-6,91	0,62	-1,89	-4,34	-7,31	-7,52
Average	3,56	-7,00	0,57	-1,98	-4,41	-7,39	-7,62
Median	3,40	-6,62	0,50	-2,06	-4,22	-6,99	-7,24
Mode	3,40	-5,58	0,76	-1,23	-3,64	-6,01	-6,20

The results are presented graphically in the next chart:



Graph 3.- Relative errors calculated with METEONORM data and the equation 3.1.

It can be observed how the results are quite dissimilar regarding to the experimental data measured in the School of Engineering. Being the best models combination the one corresponding to Orgill - Hollands and Temps - Coulson.

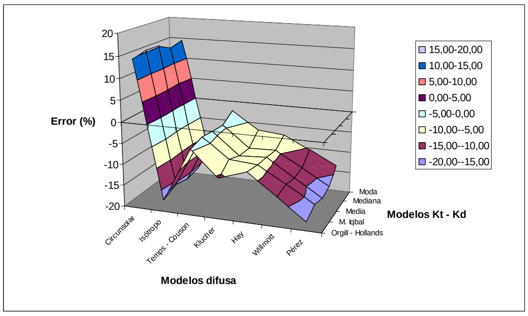
4.3.- Two axes tracking system surface

The results of the study are the relative errors considering the sign that are committed to approximate the experimental values for any of the combinations of radiation methods considered. These are presented in Table IV

Table IV: Relative errors in calculating absolute value of radiation on a surface leanig on a tracking system on two axes.

Modelos	Circunsolar	Isótropo	Temps - Coulson	Klucher	Hay	Willmott	Pérez
Orgill - Hollands	14,64	-17,24	-4,64	-10,51	-8,26	-13,11	-17,88
M. Iqbal	15,39	-15,75	-3,60	-8,23	-8,71	-12,57	-16,34
Average	15,21	-16,68	-4,12	-9,35	-9,00	-13,28	-17,32
Median	13,64	-16,11	-4,41	-9,46	-9,31	-12,94	-16,76
Mode	14,53	-13,07	**-2,44**	-6,73	-7,39	-10,42	-13,69

The next figure shows the results grafically:



Graph 4.- Relative errors in calculating absolute value of radiation on a surface leanig on a tracking system on two axes.

The test results are rather different depending on the combination of methods used. Being the most suitable pair of methods corresponding to Mode of Seville and Temps - Coulson.

5 CONCLUSIONS

The greatest differences are observed in the diffuse models while in the kt-kd models no significant differences were observed, therefore, it is more important to properly select the diffuse model.

Within the diffuse models, circumsolar model always over estimates the radiation both for static and tracking values.

The Orgill-Hollands and Perez combination shows the smallest errors in the cases of GTER and two axis tracking system database. In the case of using METEONORM database, the combination Mode-Temps-Coulson shows the smallest error.

It would be advisable to make a comparative analysis of the intraday distribution of the utilized databases.

6 REFERENCES

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