

Statistical analysis of global horizontal solar irradiation GHI in Fez city, Morocco

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Abstract. An accurate knowledge of the solar energy reaching the ground is necessary for sizing and optimizing the performances of solar installations. This paper describes a statistical analysis of the global horizontal solar irradiation (GHI) at Fez city, Morocco. For better reliability, we have first applied a set of check procedures to test the quality of hourly GHI measurements. We then eliminate the erroneous values which are generally due to measurement or the cosine effect errors. Statistical analysis show that the annual mean daily values of GHI is of approximately 5 kWh/m²/day. Daily monthly mean values and other parameter are also calculated.

1. Introduction

In the field of solar energy, it is important to know the amount of solar radiation incident on the ground at every moment, in order to properly manage solar power plants. It is therefore necessary to take measurements of all solar components at different time scales and to create databases of meteorological information. The reliability of these solar data is not always guaranteed, because the measurements of the pyranometer can be affected by several errors due to technical problems encountered during the measurement [1, 2]. A quality control of the available data has been achieved in a previous work [3].

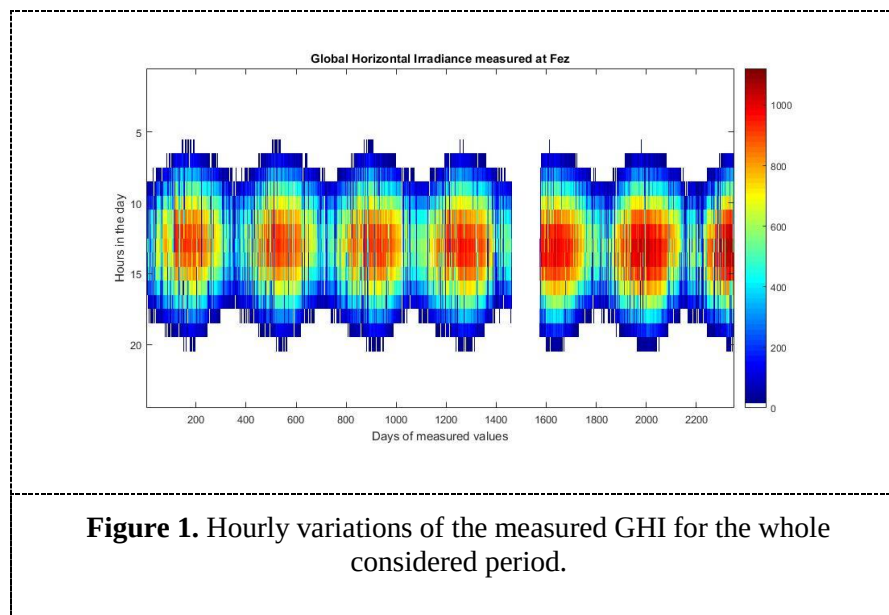
In this paper, we will statistically analyse temporal variations of global horizontal irradiation (GHI) measured for six years. This study will subsequently help researchers to evaluate the amount of energy available in Fez city to use it in other research projects.

This paper is organized as follows: the second part is dedicated to the description of the database used in this study. The third part represents the necessary processing performed on the data before exploitation. The results of the statistical analysis are shown in the fourth part.

2. Database

In this study, hourly measurements of GHI were performed using a Kip & Zonen pyranometer (model CM11). This instrument is part of a meteorological station placed on the roof of the Faculty of Sciences and Technologies of Fez (Latitude: 33° 59' 58" N, longitude: 4° 59' 22" W and altitude: 450 m). The measurement period of the database used is defined between 01/01/2009 01:00:00 GMT to 10/06/2015 at 24:00:00 GMT. Figure 1 shows the hourly variations of GHI for the whole considered period.





According to this figure, we notice the existence of a data hole in GHI measurements in the beginning of the year 2013. This is due to a problem in the connection cable of the pyranometer to the data logger.

3. Data processing

Before beginning the statistical analysis, we performed several calculation and correction techniques represented below:

- The Solar Position Algorithm (SPA) [4] was chosen to calculate the solar position at each time. SPA was developed at the National Renewable Energy Laboratory (NREL) of the U.S. Department of Energy's to calculate the sun's zenith and azimuth angles and other related parameters with an unmatched low uncertainty of ± 0.0003 degrees on a valid period of years from -2000 to 6000 [5].
- A set of quality control tests was applied to achieve an acceptable quality of GHI measurements [3]. For this purpose we relied on several previous works [2, 6, 7], and adapted modifications to our data. After applying this quality control procedure, we have 19017 hourly of GHI measures that passed all tests successfully and 6896 that have been eliminated after those tests.

4. Statistical analysis and results

In this part, we will analyse our data and present the distribution of GHI between the year 2009 and 2014. To carry out this analysis, we calculated the hourly mean, the monthly daily mean and the annual daily mean of GHI.

4.1. The mean hourly values of GHI:

Figure 2 shows the GHI mean hourly values calculated from the whole hourly values measured between 2009 and 2014. We can see a normal shape for hourly values and to be more precise we have added the error bar, which can come from the pyranometer precision (2%).

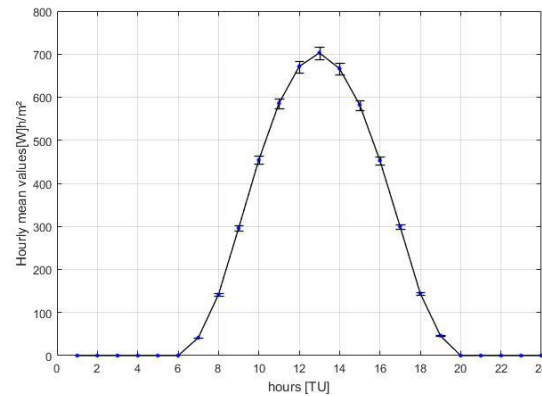


Figure 2. Mean hourly values of GHI in the city of Fez.

4.2. The daily values of GHI:

Figure 3 shows the variations of daily values. We note the presence of several missing data because there are few days that contain one or more missing hours, so to do this analyse we first eliminate those incomplete days, we consider only the day without any missed hourly value.

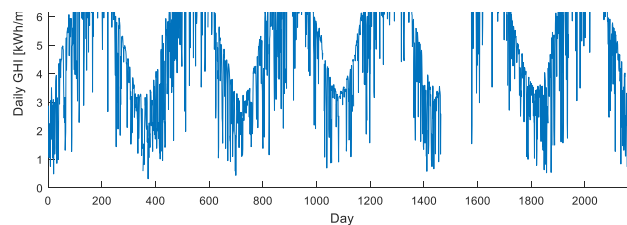
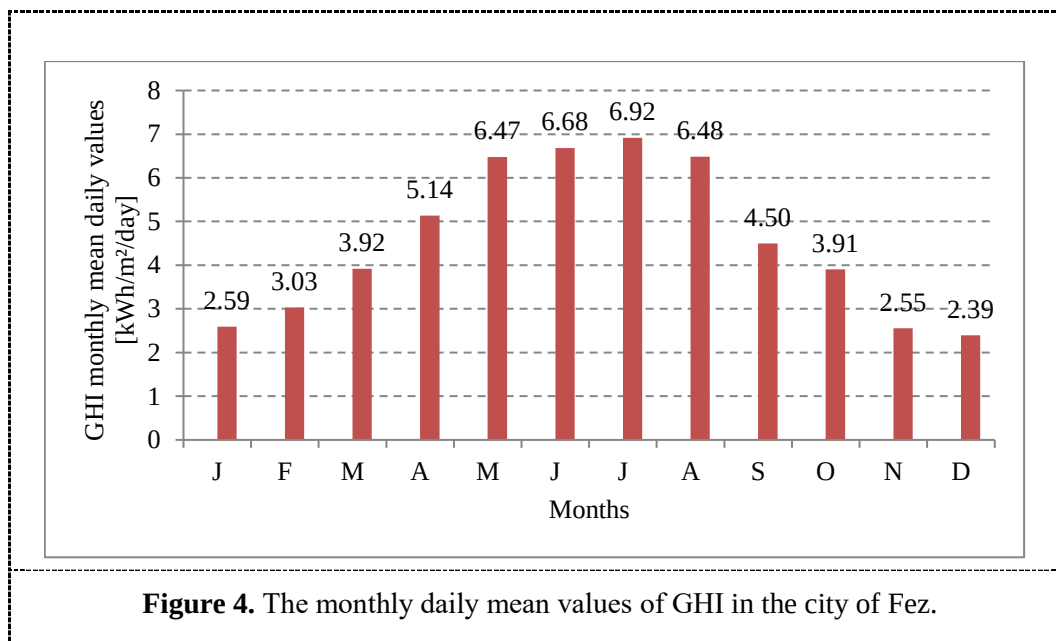


Figure 3. The daily values of GHI in the city of Fez.

4.3. The monthly daily mean values of GHI:

Figure 4 shows the monthly daily mean values ($\text{kWh/m}^2/\text{day}$). We note that the minimal value is of $2.39 \text{ kWh/m}^2/\text{day}$ and it observed in December month. We can also see that the period from May to August is well sunned: GHI exceeds $6 \text{ kWh/m}^2/\text{day}$.



4.4. The annual daily mean values of GHI:

Table 1 shows the annual daily of GHI calculated according to the number of full days corresponding to each year. We note that the annual daily mean of GHI varies slightly. The minimal observed value is 4.64 kWh/m²/day.

Table 1. The values of the annual daily mean of GHI between 2009 and 2014

Year	GHI(kWh/m²/day)	Number of full days
2009	4.80	362
2010	4.64	357
2011	4.96	357
2012	5.17	358
2013	5.72	252
2014	5.37	364

Only the year 2013 is not so longer because of the problem in the cable of the pyranometer, its annual value is calculated only for the 252 full days. By omitting this year, the mean annual daily value is of 4.99 kWh/m²/day.

5. Conclusion

The objective of this work is to analyse and evaluate the global horizontal solar irradiation measurements taken in Fez city between the year 2009 and 2014. We statistically analyse these data by calculating and representing the monthly averages, daily monthly averages and daily annual average values of GHI. We found that the minimal monthly mean daily value is of 2.39 kWh/m²/day and it observed in December month. The yearly mean GHI daily value is of approximately 5 kWh/m²/day. This shows that the region of Fez city is a good-sunned site.

6. References

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