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Measured Solar Radiation on Inclined Surface, in South West of Tunisia

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ABSTRACT

An experimental study on the solar radiation measurement in the south of Tunisia is performed using amorphous technology solar installation of 1.24 kWp power and polycrystalline technology of 1.47 kWp installed at Tozeur city. The measurements of the hourly, daily, monthly and annual solar radiation on a tilted level of 30° and in full south orientation are conducted during a period of two years. A comparison between the obtained results and the available data bases like PVGIS-CM-SAF (Climate monitoring- satellite application facility) and NASA (1993) is established. The differences between the measurements and the available databases are about 1% for CM-SAF and 17% for NASA.

Keywords: Daily solar radiation, measurement, Photovoltaic, data bases, inclined surface, Tunisia.

1. INTRODUCTION

Measurement of solar radiation is considered as the most important parameter for design and development of any solar energy system. Most researchers usually use the statistical approach to study and to predict the solar radiation trend and the methods that have been previously used and discussed in several works [1-4]. The need for solar radiation data is becoming more and more significant due to its versatility in many applications like in building planning, agriculture, health centers, power plants, analysis etc. [5], [6]. Monthly average daily solar radiation data on the earth's surface is a fundamental input and an important parameter for many aspects of climatology, hydrology, architecture, crop yield prediction, and design of solar energy-based projects [7].

Daily solar radiation data are often required in agro meteorological calculations. Also monthly mean daily data are needed for the estimation of long-term solar systems performances, but these are measured at very few weather stations. The solar radiation data is essential to the work of the potential assessment, design, planning and performance monitoring of solar energy systems. The choice of the sites for the installation of photovoltaic systems and the analysis of their performances require the knowledge of the solar irradiation data [8]. Several research works have been made to estimate solar radiation in some regions in Tunisia using different methods. BAKLOUTI et al. [6] developeda model that can be used to estimate the hourly global, diffuse and direct solar radiations for horizontal surfaces and the total daily solar radiation on an inclined and vertical surfaces in the region of Sfax, Tunisia. Moreover, the proposed method can be used to evaluate the energy production related to photovoltaic projects like solar water pumping, on-grid applications and off-grid applications in Sfax city. For the estimation of the hourly and daily solar radiations the Liu and Jordon model is used. In addition, the values of monthly of average daily solar radiation on a horizontal surface are taken from NASA data base and local meteorology station. The obtained results are compared with the PVGIS (Photovoltaic Geographical Information System) data. Other researches have been conducted regarding solar energy forecasting using the Artificial

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Neural Network techniques (ANN). Numerous meteorological and geographical variables such as maximum temperature, relative humidity, sunshine duration, cloud cover, latitude, longitude, and altitude have been used to develop the ANN models for solar prediction [7]. North Africa and the Middle East area are subject of hot climate and vast deserts located within their territories. Much solar energy is available for harvesting throughout the year. Photovoltaic energy is in full expansion in the north of Africa particularly in Tunisia, to make estimation of photovoltaic system performance, we need reliable solar radiation databases for all sites. Many solar radiation databases are available but they are quite different. Some recent control methods are discussed in [13-18].

In this paper, we present an experimental database established using two photovoltaic installations installed in Tozeur (South West of Tunisia). The first one is with amorphous technology and having 1.24 kWp of power. The second is a 1.47 kWp installation with polycrystalline technology. The solar radiation is measured for a period of two years. The effects of ambient temperature and local environmental condition on the performance of the installation are analyzed.

2. EXPERIMENT

The investigated PV System is presented in Figure 1. It's mainly constituted by two photovoltaic technologies. The first installation is with amorphous technology and having 1.24 kWp of power. The second is equipped by polycrystalline panels, with 1.47 kWp of power. This experimental device is installed in Tozeur (South West of Tunisia).

The PV generators are linked to an acquisition system used to record and convert the sensor outputs related to solar radiation, cell and ambient temperatures. Furthermore, this lab is duplicated in the north of Tunisia (Tunis). Both labs are offered by French company, Solarenr[9] in partnership with Tunisian company, TunCom[10] and have been installed in November 2013 respectively in Tozeur and in Tunis.

The aim of this experimental study is to build a reliable solar radiation database for the indicated regions of Tunisia. For this paper, the experiments were carried out during two years in Tozeur (south west of Tunisia). The station is oriented in full south with an inclination of 30° from the horizontal and taken away from any shading.

Meteorological data corresponding to the location of Tozeur is (latitude: 33°50' N, longitude: 8°082 003 E, elevation: 61m above the sea level).

Figure 2 depicts the connection mode of the solar radiation sensor. It is installed in the same orientation and inclination as the panels to provide solar radiation measurement each 5 min. The accuracy of this

Figure 1: PV system lab in Tozeur(South West Tunisia)

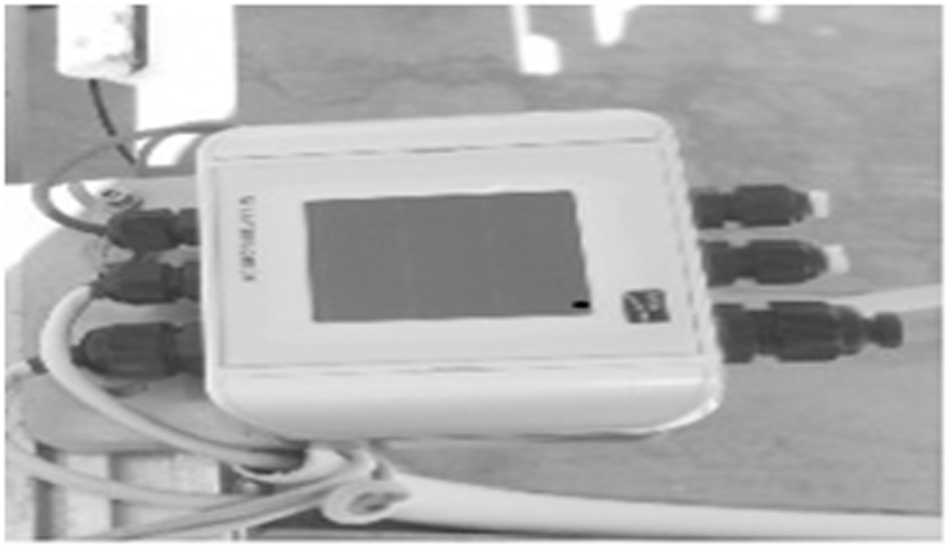

Figure 2: Solar sensor box

equipment is about 8% [11].Two temperature sensors of 0.1°C of accuracy are used to measure the panel rear face (to provide the cell temperature) and the ambient temperatures.

3. RESULTS AND DISCUSSIONS

Figure 3 shows the monthly solar radiation during a whole year (2015). As can be seen, the received annual solar radiation reaches 2375.45 kWh /m^2/year. It is obvious that the values related to the summer months (June, July, August) are more important than those of the winter months (December, January, February). This result is evident for a Mediterranean region where summer months are the sunniest and the hottest. Indeed, in summer, the number of sunshine hours is more than 10 hours. The most important monthly solar radiation of about 235.474kWh/m^2 is obtained in July. While, the least solar radiation is about 146.5 kWh/m^2, obtained in December.

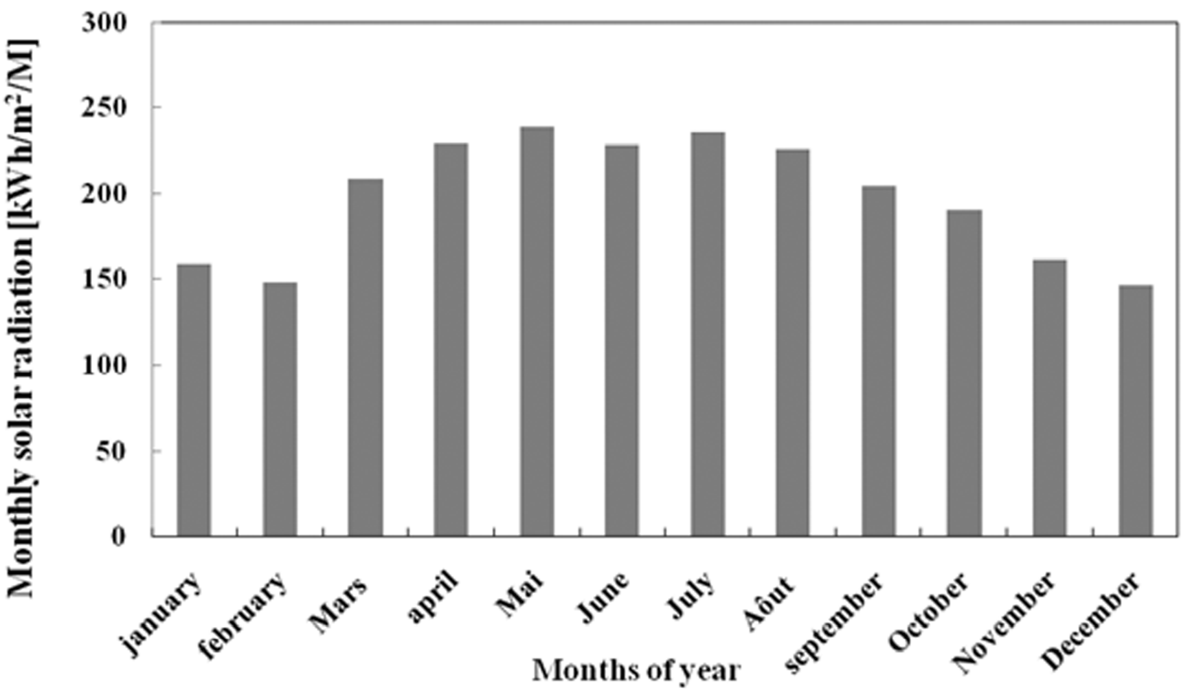

Figure 3: Monthly solar radiation on 30° inclined surface in Tozeur

Daily global solar radiation data is considered such as the most important parameter in the meteorology, solar conversion, and renewable energy, particularly for the sizing of stand-alone photovoltaic (PV) systems, in particularly battery-sizing. These results allow PV production prediction in this region. In this way we can optimize economically the cost of PV generator. These results can be generalized to the on-grid PV with backup system.

For this reason, the evolutions of daily solar radiation will be determined during different months of the four seasons.

The average variations of the solar radiation during January are presented in Figure 4. Furthermore, obtained results show that the lower values of daily solar radiation are measured in December and February due to raining days. The mean value for the winter season is about 5.04 kWh/m^2/day.

Figure 5 depicts the daily solar radiation evolution during April. In addition, For the spring season (March, April and May), the average daily solar radiation is closely near the April one and equal to about 7.35 kWh/m^2/day.

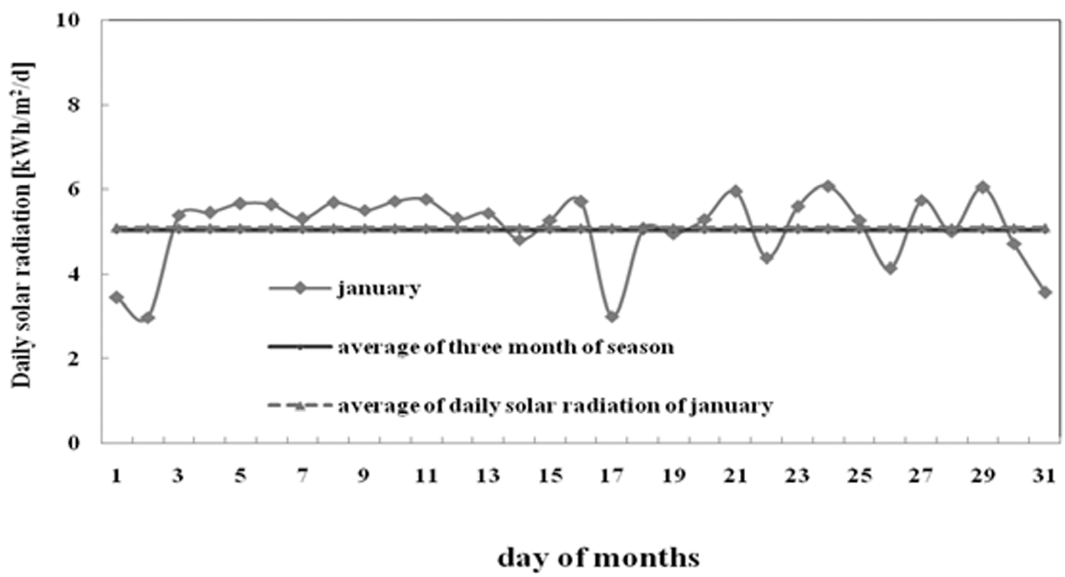

Figure 4: Daily solar radiation January

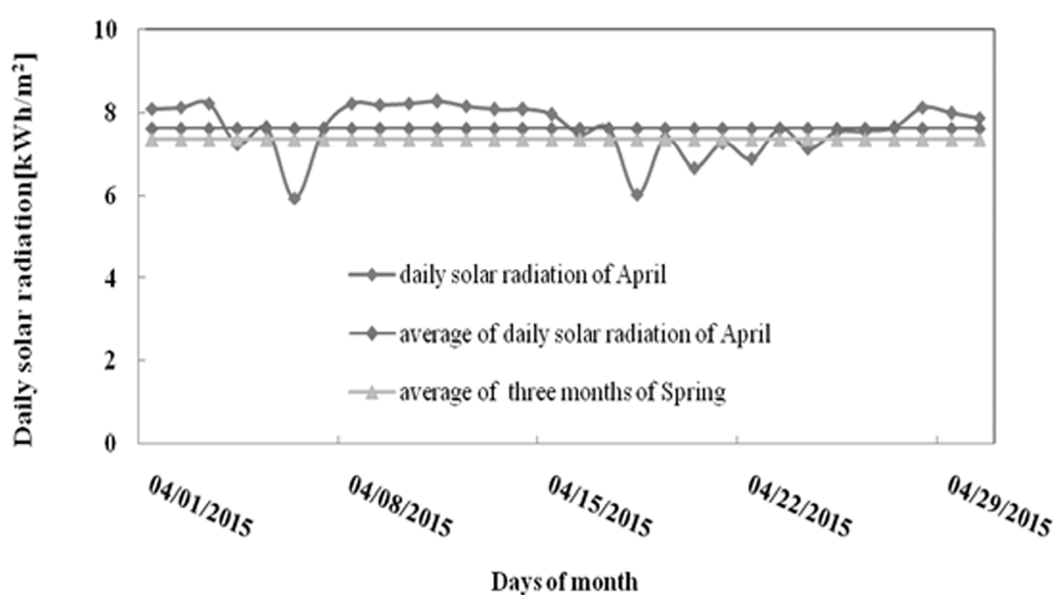

Figure 5: Daily solar radiation in April

As expected the maximum average daily solar radiation value is obtained in summer season. Figure 6 represents the daily solar radiation during July. The average value in summer season is about 7.49kWh/m²/day.

According to weather fluctuations in the local region, sensibly variations of the daily solar radiation are observed during October as shown in figure 7. Taken into consideration the other measurements in the autumn season, an average value of about 6kWh/m²/day is obtained.

The hourly solar radiation is presented in Figure 8. The maximum value reached in Tozeur region is about 1100 W/m² for summer season. That constitutes a specific advantage since the value of power density the earth's atmosphere is 1353 W/m² [12]. Furthermore obtained experimental results show that it is possible to produce PV energy even during the cloudy days as shown in Figure 9. That constitutes an important environmental favourable condition for future PV industrial investigations.

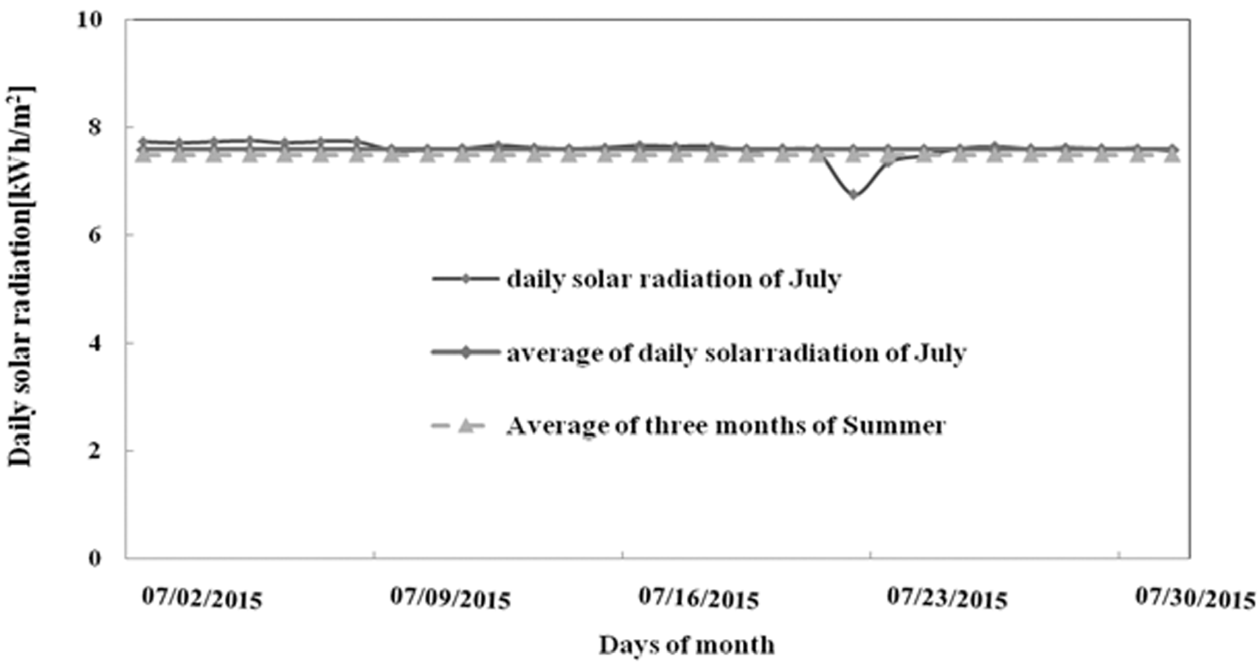

Figure 6: Daily solar radiation On July month

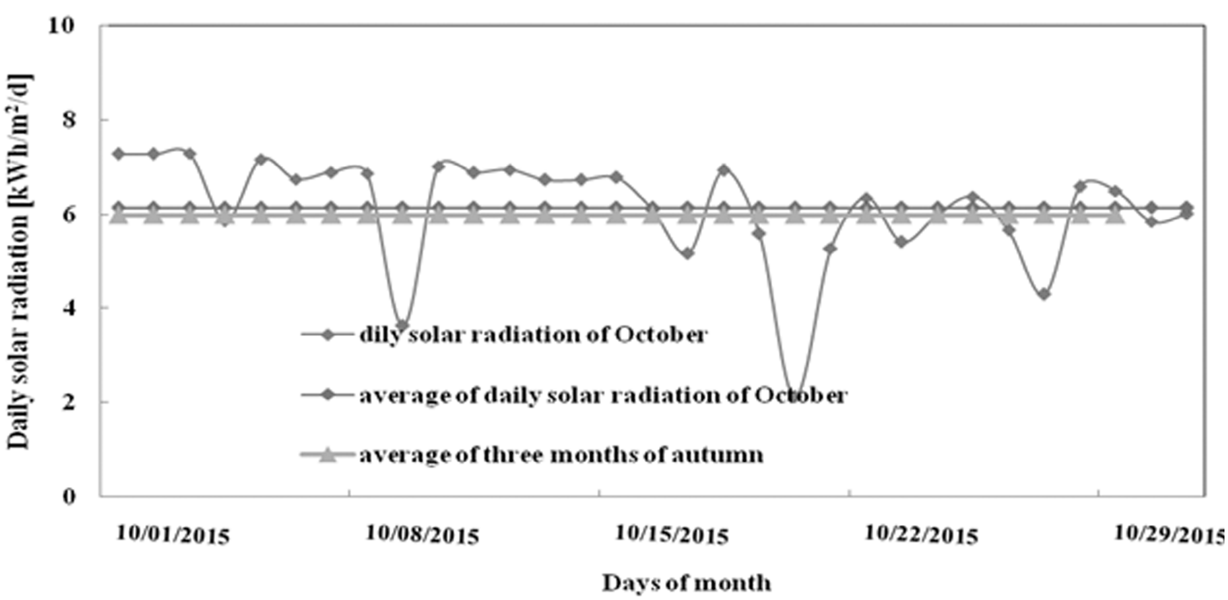

Figure 7: Daily solar radiation in October

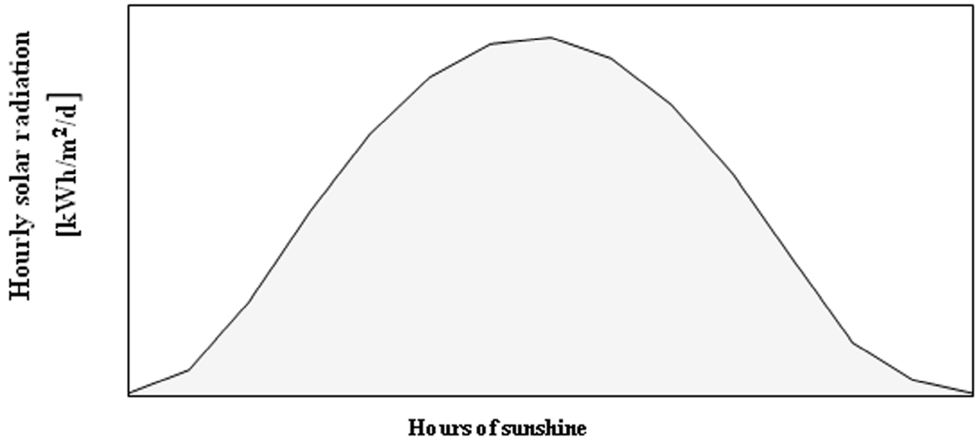

Figure 8: Hourly solar radiation in Tozeurof good sunny day (June-02-2015)

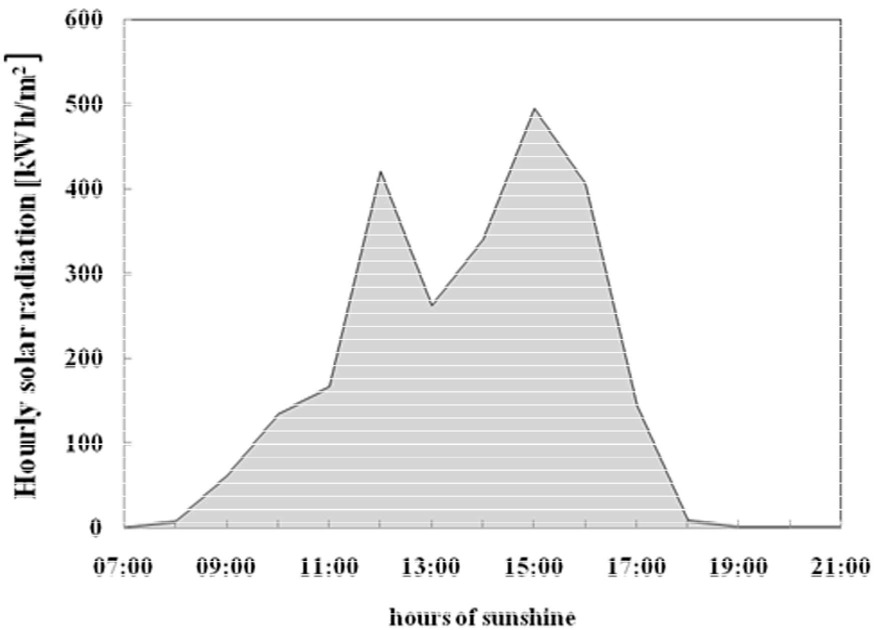

Figure 9: Hourly solar radiation in Tozeur of cloudy day (December-04-/2015)

4. COMPARISON BETWEEN DATABASES

A comparison between the annual solar radiation obtained from the actual experimental study (TunCom) and the other data bases (PVGIS and Pvsyst) is illustrated in Figure 10. A difference betwwenTunCom annual Solar radiation and 1 % for CM-SAF. While this difference is about only 17% for NASA.

Figure 11 shows the comparison between the monthly solar radiations obtained according to the three data bases. The disparity between the experimental results (TunCom) and the NASA data is more significant than that related to CM-SAF data base.

5. CONCLUSION

An experimental study is conducted on the solar radiation measurement in Tozeur (South West of Tunisia) using two PV generator technologies. The first installation is with amorphous technology and having 1.24 kWp of power. The second is equipped by polycrystalline panels, with 1.47 kWp of power. Hourly, daily and monthly solar radiation variations are measured. New database is established. The experimental results are compared to the available databases. These results constitute a powerful tool to undertake future investigations for the solar system design in the South West of Tunisia.

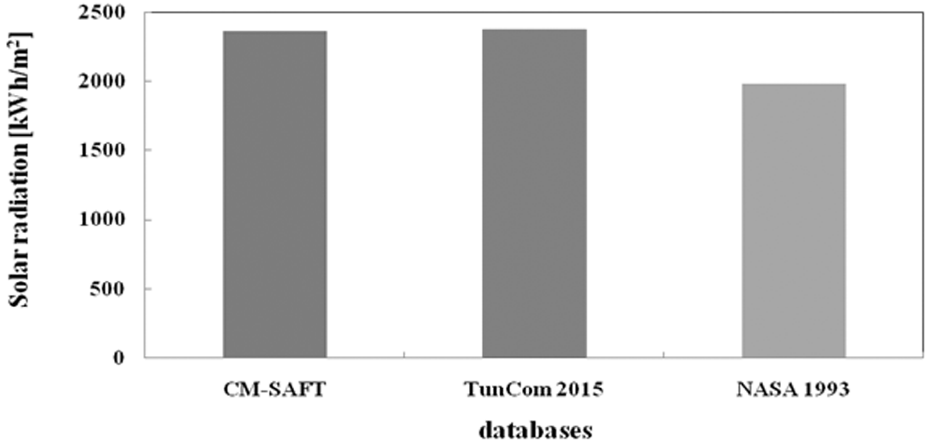

Figure 10: Annual solar radiation according to three databases

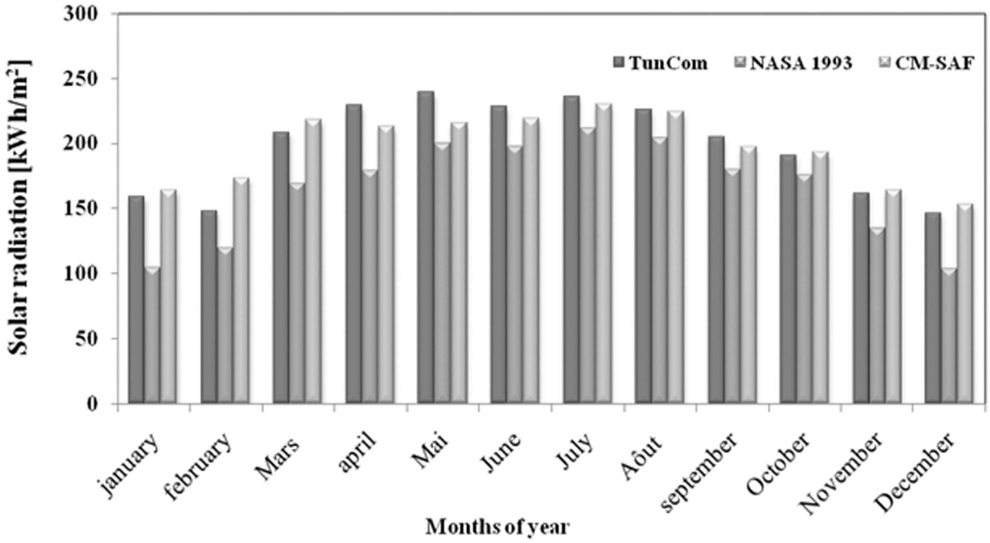

Figure 11: Monthly solar radiation in inclined surface according to three databases

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