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Measurement of global solar radiation in Terengganu state, Malaysia

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Abstract – *Accurate information on the intensity of solar radiation at a given location is essential to the development of solar energy-based projects. This information is used in the design of a project, in cost analysis, and in calculations on the efficiency of a project. As the solar radiation data are not available for most areas in Malaysia, this study is crucial in establishing the solar data for Terengganu, Malaysia. The geographical co-ordinates of the site are 5^0 $10^{'}$ N latitude 103^0 06' E longitude and 5.2 m altitude. The data used in the present study were taken from January 1 to December 31, 2004 from the recording data station installed at site by the Malaysian Meteorology Department (MMD). In addition to this, solar radiation and air temperature data taken from University Malaysia Terengganu Renewable Energy Station were also used. From the raw data, the mean, maximum and minimum hourly values were calculated. The highest daily and monthly mean global solar radiation values were 315 W/m^2 and 7555 Wh/m^2/day, respectively. The highest hourly average solar radiation intensity was 1139 W/m^2 during this study period. Yearly average daily solar energy was 18.92 MJ/m^2/day. Besides the global solar radiation, the clearness indexes and air temperature variation are discussed. This study indicates that Terengganu state has a strong solar energy potential.*

Keywords – Clearness index, daily mean solar radiation, monthly mean daily solar radiation, yearly average daily solar energy.

1. INTRODUCTION

Accurate information on the intensity of solar radiation at a given location is essential to the development of solar energy-based projects. This information is used in the design of a project, in cost analysis, and in calculations on the efficiency of a project. In particular, the clearness index of the area, in addition to other meteorological information such as humidity and, temperature for a specific period, is extremely important to assess the feasibility of a solar-driven project. Due to its geographical position in the solar belt, the Terengganu state, Malaysia is blessed with an abundance of solar energy in addition to fossil fuel. The Terengganu state has the opportunity to utilize this bounty of natural energy effectively, promoting a clean environment, and developing renewable energy technologies in the region. The use of photovoltaic devices, on the one hand, is suitable for rural electrification, pumping water from wells, cathodic protection for pipelines, telecommunications, and building facades. Solar thermal devices, on the other hand, can be used for crop drying, and water heating. Given these many possible uses of solar energy, it is important to know the global solar radiation distribution throughout the year for the state.

Global solar radiation has been measured at the few areas in the Malaysian cities [1]–[9]. Few models have been tested, and few studies based on these

models have been performed to estimate solar energy potential. The solar radiation estimates for Peninsula Malaysia were published by Chuah and Lee [1], [2] for three major towns, namely Kuala Lumpur, Penang and Kota Bharu, who used the Angstrom type regression equation to clear day radiation at the locations. Monthly average solar radiation on the horizontal surface in Kuching, Kota Kinabalu, Kota Bharu, Senai, Bayan Lepas, Kuala Lumpur, Petaling Jaya and Bandar Baru Bangi were studied by Kamaruzzaman Sopian and Mohd Yusof Othman [3], who used the simplified Angstrom model. Azami Zaharim et al. [9] used Box-Jenkins method to predict the global solar radiation at Bangi. Two statistical methods were used to forecast the monthly average daily solar radiation based on the meteorological factors such as sunshine hours, relative humidity, total rainfall and wind speed in Lapangan Terbang (airport name) Ayu Wazira Azhari et al. [8] used satellite images to predict the solar energy as an alternative method. Although solar radiation data have been reported for few regions in Malaysia, reliable and yearlong global radiation data is still needed for Terengganu state. This study therefore addresses this need.

2. EXPERIMENTAL SETUP AND PROCEDURE

In this study global solar radiation data were measured to get a better view of the solar energy potential in Terengganu state. The geographical co-ordinates of the site are 5^0 10' N latitude 103^0 06' E longitude and 5.2 m altitude. The data used in the present study were taken from January 1 to December 31, 2004 from the recording data station installed at site by Malaysian Meteorology Department (MMD) [10]. In addition to this, solar radiation and air temperature data collected from University Malaysia Terengganu Renewable Energy Station (UMT RES), which is nearly 2km northwest to the Kuala Terengganu MMD station were also used. The surface air temperature and the global solar radiation measurement instruments were set at 6 m above the ground level. A LI-COR, LI-200SZ pyranometer was used to measure the global solar radiation. Its calibration accuracy is ±2%, its linearity is 1 %, and its sensitivity is 80 μA per 1000 W/m^2. The meteorological data were collected every ten minutes using a computer. The sensors were checked and calibrated to ensure the quality of the data collected. From the raw data stored, the mean, maximum and minimum hourly values were calculated. From the hourly data set, daily and monthly statistics were made for the solar radiation and temperature data.

3. RESULTS AND DISCUSSIONS

Generally, from the data it is clear that the daily average and maximum global radiations as well as temperatures are higher from February to September and lower from October to January. Figure 1 describes the daily average and daily maximum global solar radiation for the whole year. The graphs show that the daily maximum global radiation of 1139 W/m^2 was recorded on April 5, 2004, while the highest daily average solar radiation of 315 W/m^2 was recorded on April 11, 2004. Daily mean solar radiation values were high during the periods of February to May and July to October. Average daily energy input for the whole year was 18.92 MJ/m^2/day, which agrees with the global solar map [11]. Figure 1 also shows downward excursions in northeast

monsoon, especially in November, December and January. These excursions might be due to rain and higher air mass.

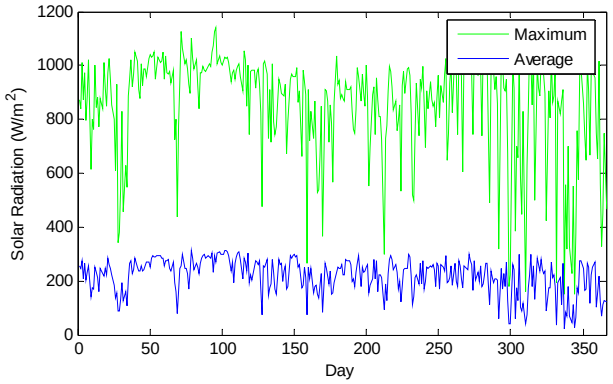

Fig. 1. Daily average and daily peak of global solar radiations throughout the year at the research site.

Daily averages for each month and peak daily global solar radiations for a complete year are shown in Figure 2. The month of April had the highest monthly average daily radiation of 6566 Wh/m^2/day and the highest daily peak in solar radiation of 7555 Wh/m^2/day. December had the lowest monthly average daily solar radiation of 3715 Wh/m^2/day.

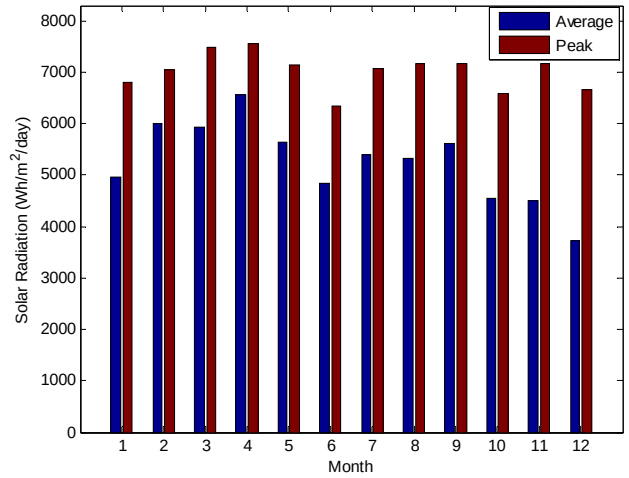

Fig. 2. Monthly average and monthly peak daily total solar radiation.

The monthly mean daily values of global solar radiation of other cities (Kuching, Kota Kinabalu and Kota Baru) of Malaysia [3] are compared with Kuala Terengganu monthly mean daily values of global solar radiation (Table 1). It is clear that the monthly average global radiation over the course of the year is higher for Kuala Terengganu, though in few months Kota Kinabalu city has higher monthly mean daily global solar radiation values.

Table 1. Monthly mean daily values of global solar radiation for Kuala Terengganu, Kuching, Kota Kinabalu and Kota Baru.

Months	Global radiation, H (MJ/m^2/day)			
	Kuala Terengganu	Kuching [3]	Kota Kinabalu [3]	Kota Bharu [3]
January	17.91	12.02	17.71	16.26
February	21.60	13.35	19.36	17.72
March	21.40	15.39	20.97	19.72
April	23.64	13.07	21.64	19.74
May	20.34	13.42	20.16	18.23
June	17.42	16.28	19.11	17.10
July	19.43	16.57	19.41	17.17
August	19.15	15.14	19.44	17.42
September	20.20	15.79	18.20	18.12
October	16.40	15.23	19.21	17.09
November	16.24	14.92	18.08	13.28
December	13.38	12.56	18.00	12.15
Annual Average	18.92	14.48	19.27	17.00

Figure 3 shows the maximum, minimum and average air temperature for one complete year for Kuala Terengganu. The graph shows that during the northeast monsoon the air temperature was lower than 30.0 °C when the solar radiation was lower than 5000 Wh/m^2/day. The highest daily maximum and monthly average temperatures were 34.5 °C and 29.4 °C on 31 August and April, respectively. The minimum daily average temperature recorded was 22.8 °C on February 22.

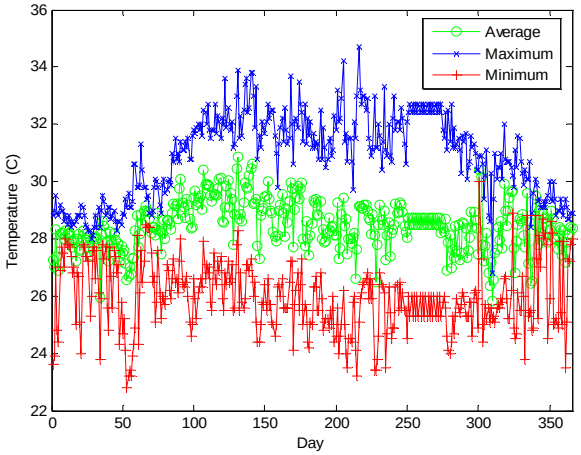

Fig. 3. Daily average, minimum and maximum temperatures throughout the year.

Figure 4 shows the maximum, minimum and average air temperature for for Kuala Terengganu in 2004.

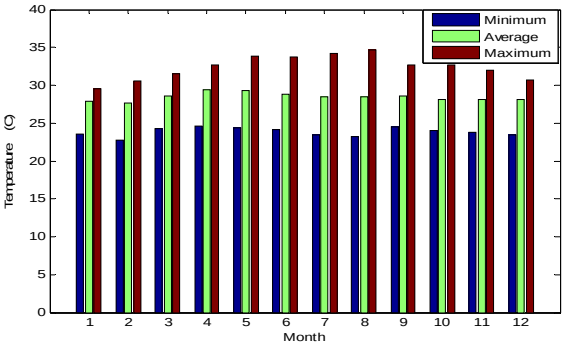

Fig. 4. Monthly average daily mean, minimum and maximum temperatures.

Figure 5 shows the daily variations of the clearness index for Kuala Terengganu throughout the year. The clearness index varies between 0.06 and 0.76 during one complete year. During the northeast monsoon, the clearness indexes are very low; for other periods almost clear sky condition exists.

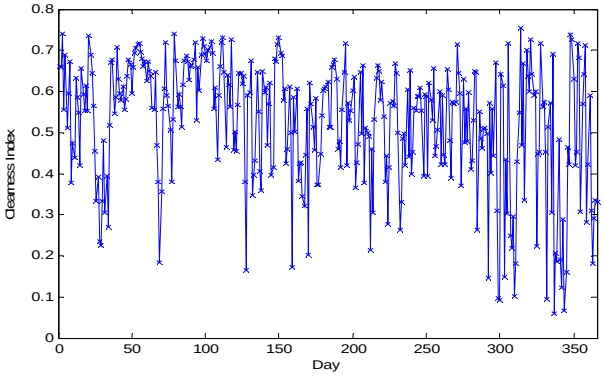

Fig. 5. Daily average clearness index variation throughout the year.

The monthly average clearness index is shown in Figure 6 and it varies between 0.42 and 0.64. The average clearness index value is approximately 0.53. During the northeast monsoon, when both the clearness index and temperature are low, global solar radiation is likely to be low. Due to the low clearness index the solar radiation energy will reduces dramatically

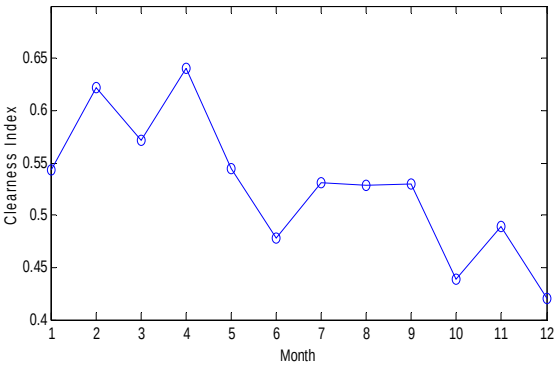

Fig. 6. Monthly average clearness index

Table 2. Monthly and annually average clearness index of Kuala Terengganu, Kuching, Kota Kinabalu and Kota Baru

Months	Clearness Index			
	Kuala Terengganu	Kuching [3]	Kota Kinabalu [3]	Kota Baru [3]
January	0.54	0.35	0.55	0.51
February	0.62	0.38	0.57	0.52
March	0.57	0.41	0.56	0.53
April	0.64	0.36	0.59	0.54
May	0.54	0.37	0.53	0.48
June	0.48	0.48	0.53	0.48
July	0.53	0.45	0.51	0.45
August	0.53	0.41	0.51	0.46
September	0.53	0.43	0.50	0.50
October	0.44	0.41	0.53	0.47
November	0.49	0.41	0.53	0.39
December	0.42	0.36	0.54	0.37
Annual Average	0.53	0.40	0.54	0.47

The monthly mean clearness indexes of other cities (Kuching, Kota Kinabalu and Kota Bharu) of Malaysia [3] are compared with Kuala Terengganu monthly mean clearness index, as shown in Table 2. It is clear that the monthly average clearness index over the course of the year is higher for Kuala Terengganu, though in few months Kota Kinabalu city have higher monthly mean clearness index values.

4. CONCLUSIONS

In this study global solar radiation and meteorological data were measured to get a better view of the solar energy potential in Kuala Terengganu. Daily average solar radiation data show that average values are lower in the northeast monsoon from November to January and are higher in the other periods. The maximum global radiation of 1139 W/m^2 was recorded on April 5, 2004, while the highest daily average solar radiation of 315 W/m^2 was recorded on April 11, 2004. Average daily energy input for the whole year was 18.92 MJ/m^2/day.

The highest daily maximum and monthly average temperatures were 34.5 °C and 29.4 °C on 31 August and April, respectively. The minimum daily average temperature was recorded 22.8 °C on February 22. In northeast monsoon the air temperature lowers than 30.0 °C.

The clearness index varies between 0.06 and 0.76 during one complete year. In northeast monsoon, the clearness indexes are very low, but other periods almost clear sky condition exists. The monthly average clearness index varies between 0.42 and 0.64. The average clearness index value is approximately 0.53. In northeast monsoon, clearness index, temperature and solar radiations are low.

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