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Diurnal and Seasonal Variations of Global Solar Radiation in Akure, Ondo State, South Western Nigeria

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ABSTRACT
In this paper, the diurnal and seasonal variations of Global Solar Radiation have been studied by analyzing one year data from January 2011 to December 2011 at an interval of five minutes on the 15th and 30th days of each month except for February. Data were measured at the ground surface in a tropical station of Akure (7.15^0N, 5.12^0E), Ondo State, Nigeria. Diurnal variations of solar radiation for typical months of dry and rainy seasons were studied by considering the variation of the global solar radiation as a function of time for each month, we observed that the analysis for the diurnal variations showed that the solar radiation values rose steadily from dawn and attained their peaks between 12:00 hLT and 14:00 hLT after which the values fall to a minimum in the late afternoon and evening periods at about 18:30 hLT. For the seasonal variation, we consider the global solar radiation at 12:00 hLT, 15:00 hLT and 18:00 hLT, the peaks were observed around February, March and April at 12:00 hLT and 15:00 hLT while the minimum was recorded around June and October at 18:00 hLT, this explains maximum incident solar radiation during the day and little or no incident solar radiation at night.

Keywords: Diurnal variation, Seasonal variation, global solar radiation, dry months, wet months, Akure.

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I. INTRODUCTION

Solar radiation is the main source of energy that drives physical, chemical and biological processes. The solar radiation reaching the earth's surface depends on the climatic condition of the specific site location, and this is essential for accurate prediction and design of a solar energy system.

When global solar radiation is used to generate electrical energy for any specific site location, 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 (Alam *et al*., 2005). Although solar radiation data are available in most meteorological stations, many stations in developing countries (including Nigeria) suffer from a shortage concern of these data. Thus, alternative methods for estimating these data are required (Al-Salihi *et al*., 2010). One of these methods is the use of empirical models. Accurate modeling depends on the quality and quantity of the measured data used and is a good tool for generating global solar radiation at locations where measured data are not available.

Diurnal variations of precipitation are an important aspect of regional climate because precipitation occurring regularly during a particular time of the day is connected with the regional and local atmospheric circulation and/or dynamics. This is why diurnal variations simulated by a climate model are often checked with observation (Chen *et al*., 1996; Collier and Bowman, 2004; Knievel *et al*., 2004). On the other hand, verified climate models can enhance the understanding of mechanisms that cause diurnal variations (Dai *et al*., 1999; Mapes *et al*., 2003; Zhang, 2003; Dai and Trenberth, 2004; Li *et al*., 2004; Liang *et al*., 2004; Woolnough *et al*., 2004).

The temporal variation of the amount of solar radiation incident at any location on the earth's surface basically depends on astronomical, geographical and climatic factors (concentrations of water vapour, aerosols and clouds in atmosphere). According to Liou (2002), the seasonal variations in the levels of each component of solar radiation rely on the interaction with the atmosphere. Some atmospheric constituents are relatively constant in concentration (permanent gases), while others are highly variable in time and space (such as CO_2, methane, water vapour and aerosols), thus allowing that the current composition and concentration vary with geographical location, altitude and season of the year.

In this study, an in-situ measurement of solar radiation has been carried out in Akure, Ondo State, south-western Nigeria. The diurnal and seasonal variations of the Global solar radiation has been analyzed and discussed to ascertain the period of availability of the solar radiation in this locality. Compare the global radiation in the dry season to that of the rainy season; and study the seasonal variations of solar radiation in the study area.

II. MATERIALS AND METHODS

A five minute NECOP climate data which includes Rainfall, Global Solar Radiation, Temperature, Relative Humidity, Wind Speed, Wind Direction, Pressure and Rain – rate for a continuous 12 months from 1st January 2011 to 31th December 2011 from Akure (7.15^0N, 5.12^0E) was obtained using the equipment of the Nigerian Environmental Climatic Observing Programme (NECOP) installed on a short mast at The Federal University of Technology, Akure, Ondo State, Nigeria. However, the global solar radiation at an interval of five minutes on the 15th and 30th days of each month of the year except for February which is on the 15th and 28th days was utilized in this study.

The solar radiation measured is a measure of the intensity of the sun's radiation reaching a horizontal surface. The irradiance includes both direct component from the sun and the reflected component from the rays of the sky. The solar radiation readings give a measure of the amount of solar radiation hitting the solar radiation sensor at any time, expressed in W/m^2.

The measurement covered both main seasons occurring in Akure every year, that is, the rainy season and the dry season. The rainy season months are from April to October, while the dry season months are from November to March. The climate in Akure is tropical and is governed by the movement of the inter-tropical discontinuity, a zone where warm moist air from the Atlantic converges with hot, dry and sometimes dust-laden air from the Sahara known locally to be harmattan. High temperatures and high humidity also characterize the climate. The rainfall is about 1524mm per year. The atmospheric temperature ranges between 28^oC and 31^oC and a mean annual relative humidity of about 80 per cent.

In order to account for the diurnal variation of global solar radiation, a time series plot of global solar radiation was plotted for the 15th and 30th days of the every month of the year, except for the month of February as 15th and 28th day. Also, a time series plot of global solar radiation was also done to study the seasonal variations of solar radiation in the study area.

III. RESULTS AND DISCUSSION

For the purpose of the discussion of our analyzed results, morning hours is between 00:00 and 12:00 hLT, afternoon hours is from 12:00 hLT to 16:00 hLT, evening hours is from 16:00 hLT to 20:00 hLT and night hours from 20:00 hLT to 00:00 hLT.

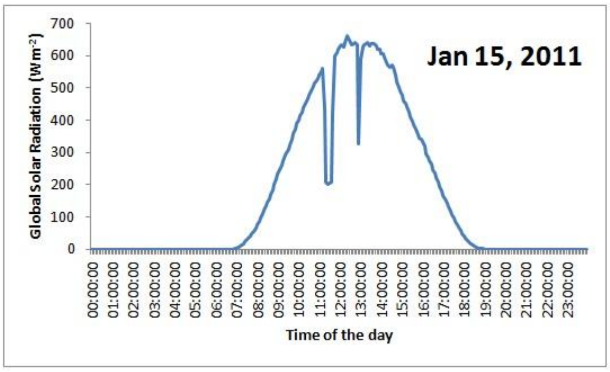

Figure 1: Diurnal plot of Global Solar Radiation for January 15, 2011

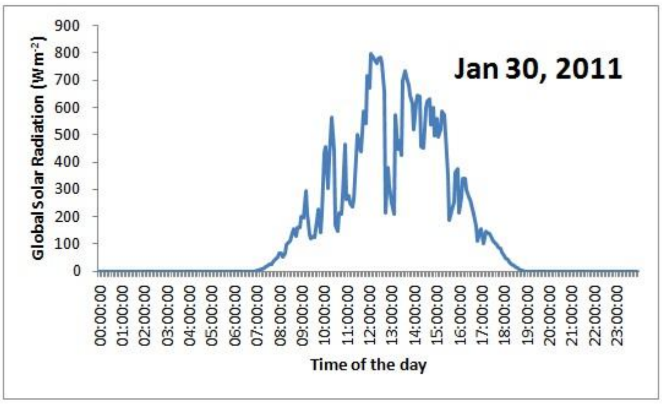

Figure 2: Diurnal plot of Global Solar Radiation for January 30, 2011

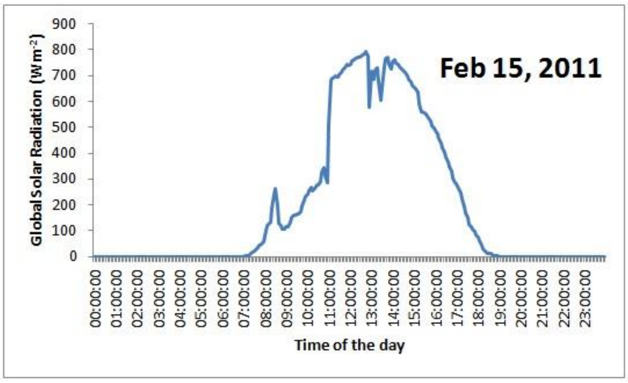

Figure 3: Diurnal plot of Global Solar Radiation for February 15, 2011

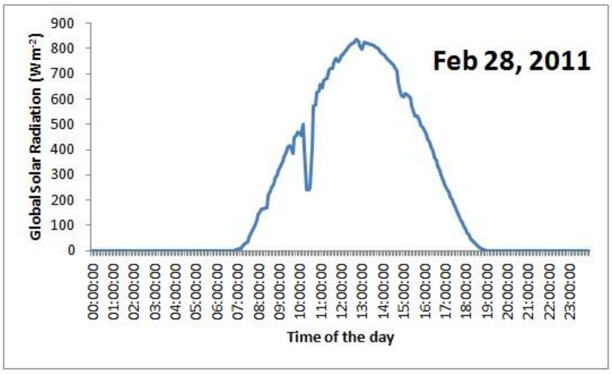

Figure 4: Diurnal plot of Global Solar Radiation for February 28, 2011

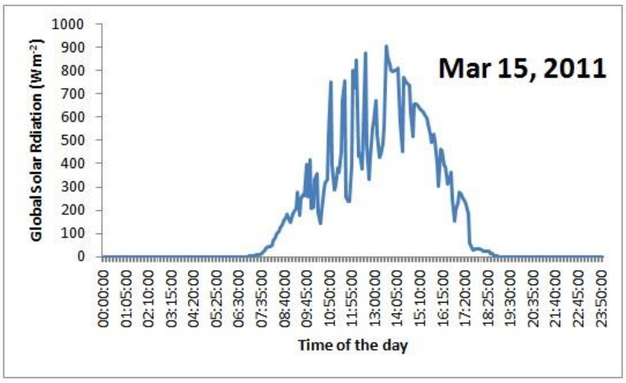

Figure 5: Diurnal plot of Global Solar Radiation for March 15, 2011

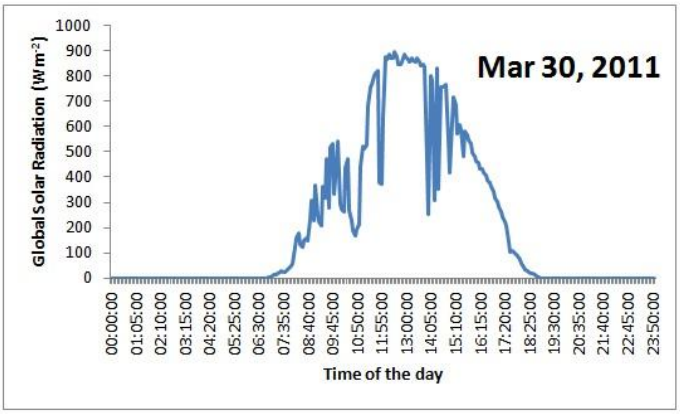

Figure 6: Diurnal plot of Global Solar Radiation for March 30, 2011

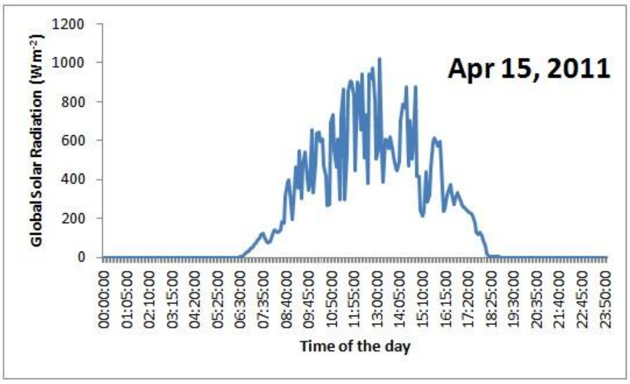

Figure 7: Diurnal plot of Global Solar Radiation for April 15, 2011

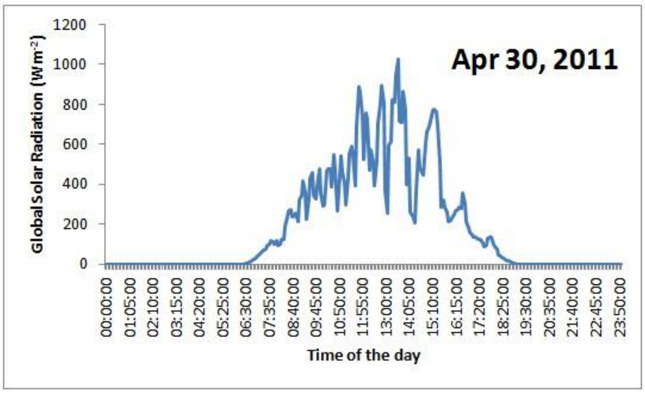

Figure 8: Diurnal plot of Global Solar Radiation for April 30, 2011

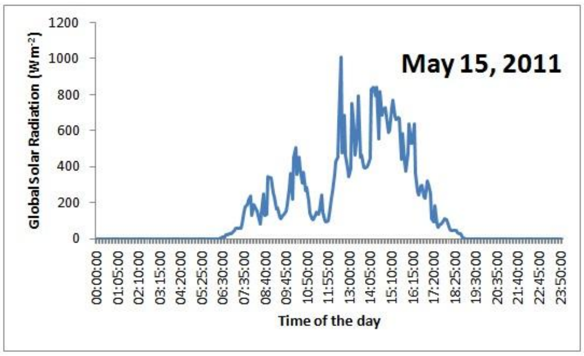

Figure 9: Diurnal plot of Global Solar Radiation for May 15, 2011

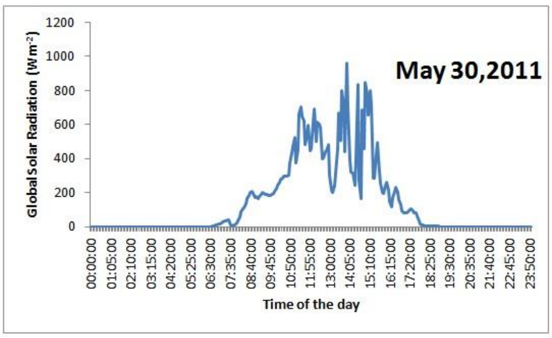

Figure 10: Diurnal plot of Global Solar Radiation for May 30, 2011

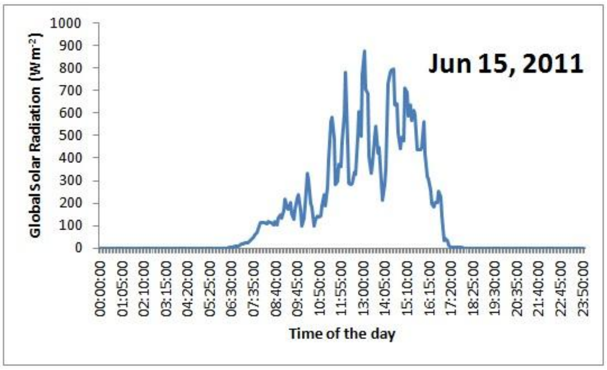

Figure 11: Diurnal plot of Global Solar Radiation for June 15, 2011

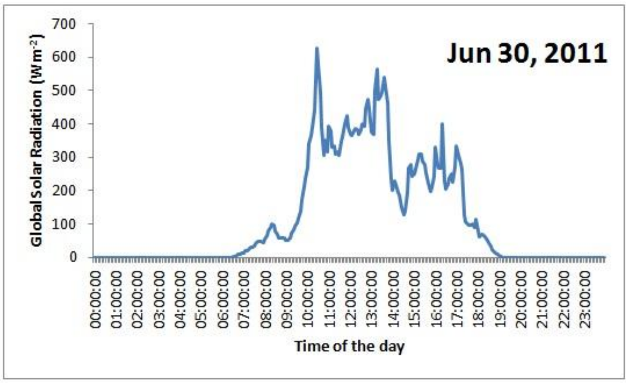

Figure 12: Diurnal plot of Global Solar Radiation for June 30, 2011

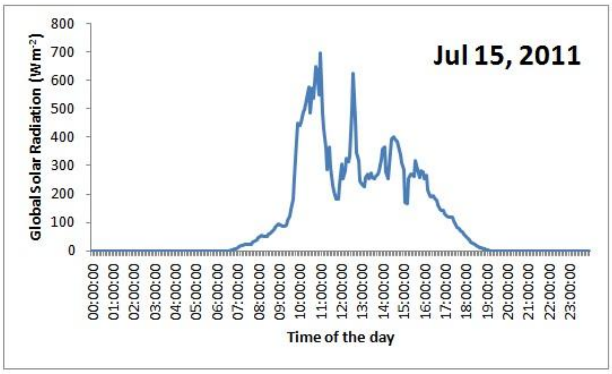

Figure 13: Diurnal plot of Global Solar Radiation for July 15, 2011

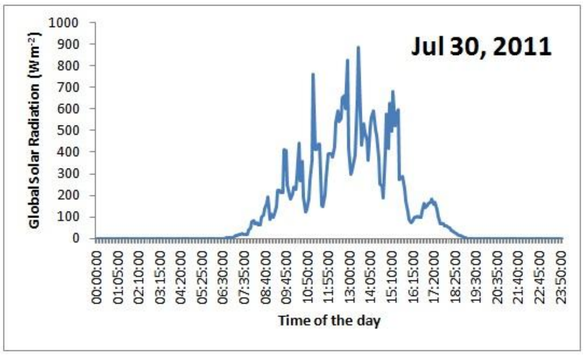

Figure 14: Diurnal plot of Global Solar Radiation for July 30, 2011

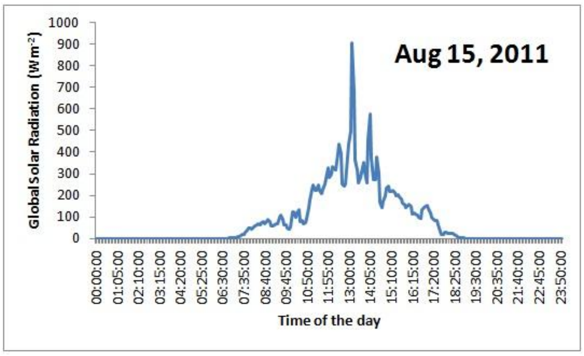

Figure 15: Diurnal plot of Global Solar Radiation for August 15, 2011

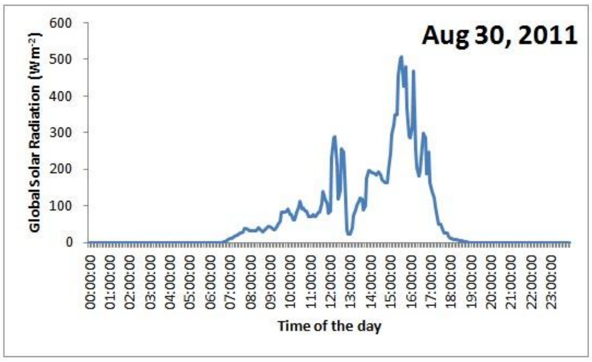

Figure 16: Diurnal plot of Global Solar Radiation for August 30, 2011

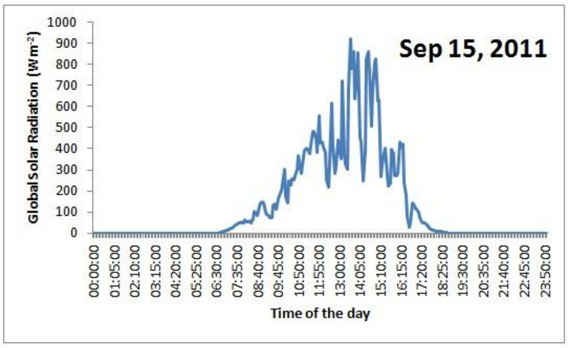

Figure 17: Diurnal plot of Global Solar Radiation for September 15, 2011

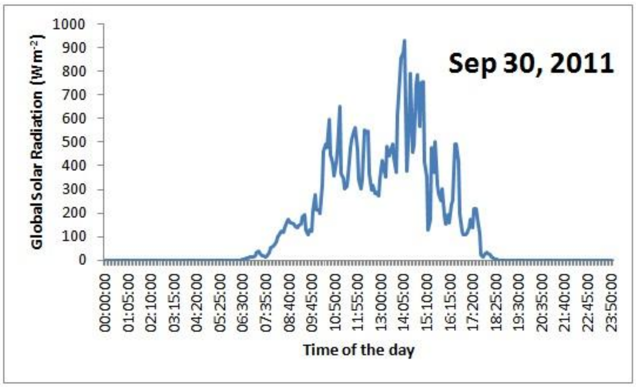

Figure 18: Diurnal plot of Global Solar Radiation for September 30, 2011

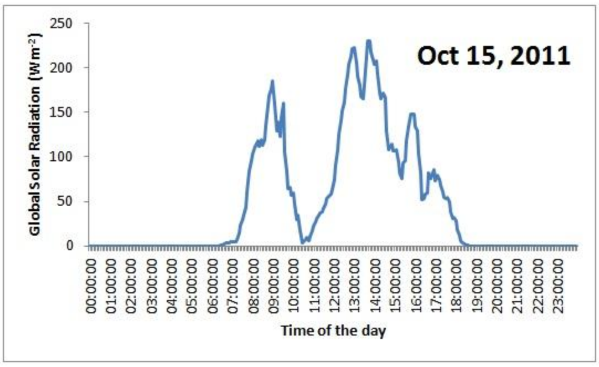

Figure 19: Diurnal plot of Global Solar Radiation for October 15, 2011

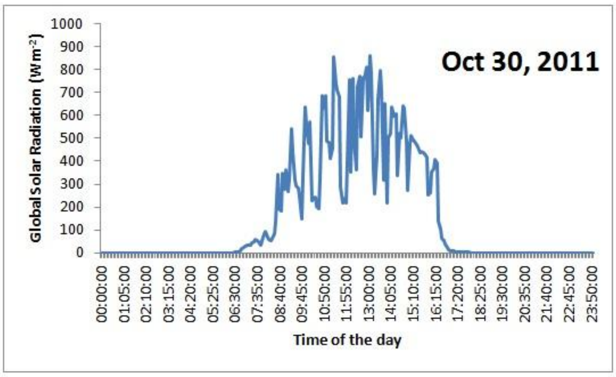

Figure 20: Diurnal plot of Global Solar Radiation for October 30, 2011

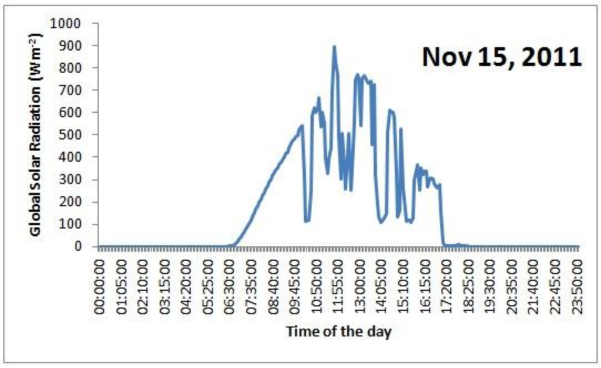

Figure 21: Diurnal plot of Global Solar Radiation for November 15, 2011

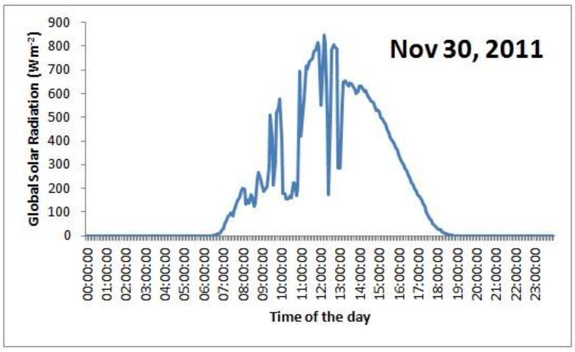

Figure 22: Diurnal plot of Global Solar Radiation for November 30, 2011

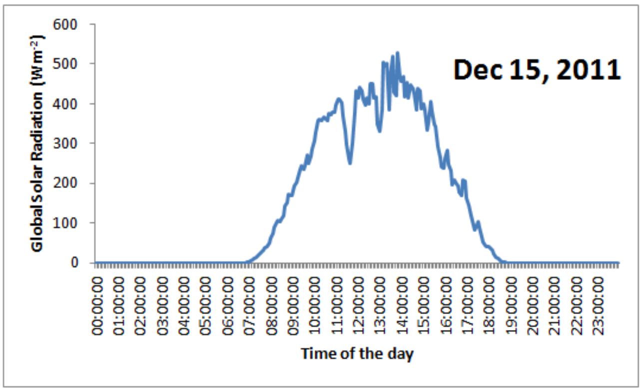

Figure 23: Diurnal plot of Global Solar Radiation for December 15, 2011

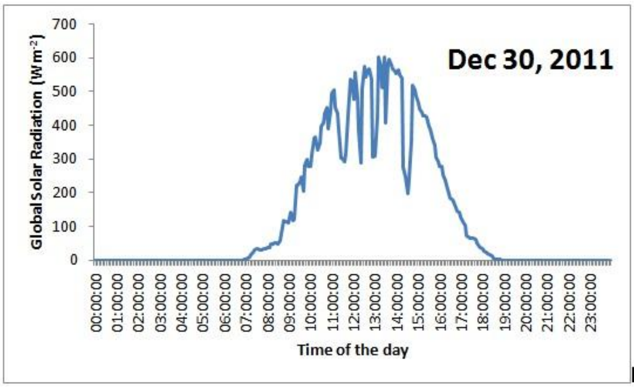

Figure 24: Diurnal plot of Global Solar Radiation for December 30, 2011

Diurnal Variation Analysis

The diurnal plots of Global Solar Radiation figures (1 to 24) show a steady rise in global solar radiation received at the surface after 6:30 hLT. Peaks in global solar radiation received at the surface were observed between 12:00 hLT and 14:00 hLT on almost all the diurnal plots, which steadily reduced to minimum after 18:30 hLT. Wriggling distribution with jagged edges were observed in the course of the day which show fluctuations in the amounts of global solar radiation at the surface and this is traceable to the effect of clouds which imposes scattering, reflections, and transmission effects on incoming solar radiation from the sun. The dry months have comparatively slightly larger values of global solar radiation than the wet months.

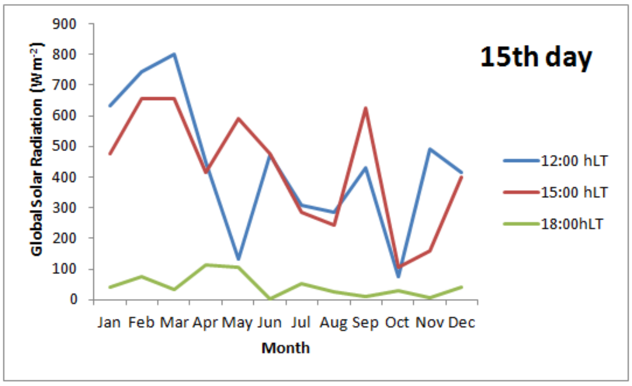

Figure 25: Seasonal plot of Global Solar Radiation for 15th day of the month

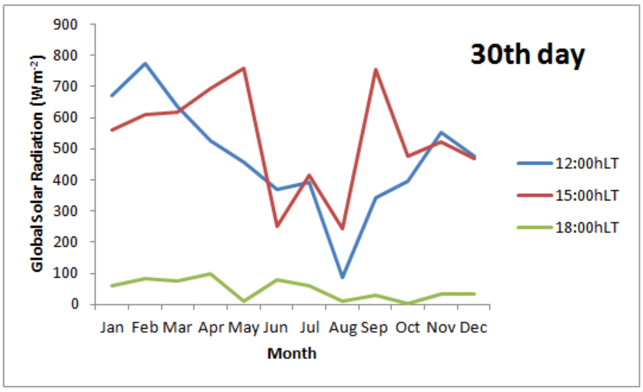

Figure 26: Seasonal plot of Global Solar Radiation for 30th day of the month

Seasonal Variations Analysis

Figure 25 shows the observed global solar radiation at 12:00 hLT, 15:00 hLT and 18:00 hLT on the 15th day of each month in the year. At 12:00 hLT, high radiation values were recorded for the first three (3) months of the years namely; January, February and March. Reduction in the received radiation was observed between June and August, and a slight increase in global solar radiation was observed in September, which was also accompanied by the least radiation measured in October, and subsequently increases in the months between November and December. However, the maximum value of global solar radiation at 12:00 hLT on the 15th day was observed in the month of March and minimum in October.

At 15:00 hLT, high values of global solar radiation were recorded in the months of February, March, May and September. However, the maximum value at 15:00 hLT on the 15th day was observed in the month of March and the least in October.

At 18:00 hLT, the global solar radiation received at the ground level reduces to a maximum of about 112W/m^2 in the month of April compared with a maximum of 800W/m^2 observed at mid-day in the month of March. Also, global solar radiation approaching zero were observed at this hour for the months of June, September and November.

Figure 26 shows the observed global solar radiation at 12:00 hLT, 15:00 hLT and 18:00 hLT on the 30th day of each month in the year. At 12:00 hLT, high radiation values were recorded in the month of February and the least in August.

At 15:00 hLT, high values of global solar radiation were recorded in the months of January to May and September. However, the maximum value at 15:00 hLT on the 30th day was observed in the month of May and the least in August.

At 18:00 hLT, the global solar radiation received at the ground level reduces to a maximum of about 100W/m^2 in the month of April compared with a maximum of 773.8W/m^2 observed at mid-day in the month of February. Also, global solar radiation approaching zero were observed at this hour for the months of August and October.

IV. CONCLUSION

In this manuscript, the diurnal and seasonal variations of global solar radiation measured at Akure, Ondo State, South Western, Nigeria was analyzed. The global solar radiation picks up after 6:30 hLT and increases steadily with time until diurnal peaks is reached within the time interval of 12:00 hLT and 14:00 hLT in almost all the diurnal plots and begins to fall steadily after 18:30 hLT then subsequently becomes zero during the remaining time of the night, wriggling distribution with jagged edges were observed during the day attributing to fluctuations of solar radiation caused by the effect of aerosols, clouds and atmospheric gases, thereby reducing the amount of solar radiation reaching the earth surface which tends to be more pronounced in the wet months.

The result shows maximum value in the month of March at 12:00 hLT on the 15th day with 800 W/m^2 and minimum in October with 74.39 W/m^2. The results further show larger values of global solar radiation in the dry months, i.e. dry season (November – March) when compared to wet months, i.e. rainy season (April – October) and this is in good agreement with that reported by (Falodun and Ogolo, 2007).

It was observed that at night times, from 20:00 hLT throughout the year the solar radiation is less than 1 W/m^2 and becomes zero from 22:00 hLT. However, the seasonal variations also show that during the day times, especially between 12:00 hLT and 15:00 hLT appreciable high variation of global solar radiation values were recorded and low values at 18:00 hLT on the 15th and 30th days of each month.

From the above explanation, we can safely conclude that the diurnal and seasonal variations are due to variation in solar radiation. The observed variation may be attributed to the fact that solar constant is not perfectly constant, but varies in relation to the solar activities (Akpootu and Gana, 2013).

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