Modified Angstrom Solar Radiation Model for Lagos Nigeria

Emetere M.E. 1, Emetere J.M. 2, and Dania O.E. 3
Department of Physics, Covenant University Canaan land, P.M.B 1023, Ota, Nigeria.
Department of Mechanical Engineering and Science, University of Johannesburg,
APK, South Africa
Department of Mathematics, Federal University of Technology, Minna, Nigeria
Department of Biochemistry, Covenant University Canaan land, Ota, Nigeria
E-mail: emetere@yahoo.com

Abstract. Solar energy generation in tropical climate system is said to be a viable project because of the availability of solar radiation. The use of solar photovoltaic (PV) panel in the research area is encouraging at the moment but the issue has been that the lifespan of the PV panel is somewhat very low. This research aims to determine the solar radiation model for Lagos to enhance the optimization of the production of solar PV panels for Lagos Nigeria. This would enhance higher patronage in the commercial hub of Nigeria.

Keywords: energy, solar, solar radiation, meteorology, solar energy, renewable energy

1. Introduction
In the tropical climate system, solar energy generation is adjudged to be at its peak due to abundant sunshine. However, this can be argued because different solid-state devices are currently emerging which requires low solar radiation to attain maximum solar energy generation. Solar devices are devices that make use of the solar irradiance to generate heat or electricity. Solar devices can be divided into either passive or active solar devices. In recent time, the adoption of solar device (solar photovoltaic (PV) panel) is gaining higher patronage in the research site. At the moment, only standalone users patronize PV panels because of low energy supply via the national grid system [1]. The research site (Figure 1) is the commercial hub of Nigeria. Hence, the adoption of source of energy generation for standalone users is lucrative and laudable. At the moment, fossil fuel generators are still majorly in use in the research site. With the high state of air pollution in the region [2], the use of fossil fuel should be mitigated to allow for the drastic reduction of anthropogenic emissions. The renewable energy source awareness is encouraging, as most researchers have demonstrated that the populace have shown great enthusiasm for the adoption of solar devices for energy generation [3]. However, early users of solar panels have complained that the lifespan of the PV panel is low at the moment (average of 4 to 7 years). Hence, the huge cost of setting up a solar PV panel and its maintenance would not be economical if the system packs-up within a short time of usage. Based on the above, the patronage of solar devices have reduced. There are many factors affecting the lifespan of PV panels in tropical region [4]. However, the main is the solar spectra filtering on PV panels. The solar cells in the PV panels react to this spectra and shutdown with time. In this research, we will derive the solar radiation model over the research site. It is believed that this initiative would guide PV panel companies to better understand why patronage is low at the moment in the research site.
2. Methodology

The dataset that was used for this research was obtained from the Nigerian Metrological Agency (NIMET). Fourteen years dataset (1981-1994) was used for the research. The sunshine hour and solar irradiation dataset was extracted from the bulk dataset. The dataset where used to obtain the required parameter for the solar radiation model. The average monthly global radiation model as derived by Angstrom[5] and modified by Page[6] and Prescott [7] is given as:

\[
\frac{H}{H_o} = a - b \left( \frac{S}{S_o} \right)
\]  

(1)

\( H \) =monthly average global radiation, \( H_o \) = monthly average daily extraterrestrial radiation, \( S \) = monthly average daily bright sunshine hour, \( S_o \) = maximum possible monthly average daily hour, \( a=\text{b} \) = constants.

The monthly average daily extraterrestrial radiation is calculated as:

\[
H_o = \frac{24}{\pi} I_{sc} \left[ 1 + 0.33 \cos \left( \frac{360D}{365} \right) \right] \times \left[ \cos \theta \cos \delta \sin \omega_s - \frac{2\pi \omega_s}{360} \sin \delta \right]
\]  

(2)
\( \omega_s \) = sunset hour angle, \( I_{sc} \) = solar constant, \( L \) = latitude of location, \( \delta \) = declination angle, \( \mathcal{D}_n \) = day of the year starting from January

\[
\omega_s = \cos^{-1}\left(-\tan L \tan \delta\right)
\]  
(3)

\[
\delta = 23.45 \sin \left(\frac{360(284-\mathcal{D}_n)}{365}\right)
\]  
(4)

\[
S_p = \frac{Z}{15} \cos^{-1}\left(-\tan L \tan \delta\right)
\]  
(5)

The regression model was used to obtain the value of ‘a’ and ‘b’

3. Results and Discussion

The monthly variation was used to calculate the constants (‘a’ and ‘b’) for Lagos. For January, the modified Angstrom model (MAM) is given as:

\[
\frac{N}{N_p} = 6.457 + 0.142\left(\frac{X}{S_p}\right)
\]  
(6)

The linear regression for this result is 14.8%. Though the result is low, however, it should be noted that the relationship depends on the measured data provided by NIMET.

The result for February is displayed as:

\[
\frac{N}{N_p} = 9.043 + 0.038\left(\frac{X}{S_p}\right)
\]  
(6)

The linear regression for this result is 8.16%.

The result for March is displayed as:

\[
\frac{N}{N_p} = 0.37 + 0.075\left(\frac{X}{S_p}\right)
\]  
(7)

The linear regression for March result is 8.16%. The result for April is displayed as:

\[
\frac{N}{N_p} = 7.68 + 0.098\left(\frac{X}{S_p}\right)
\]  
(8)

The linear regression for April result is 10.8%. The result for May is displayed as:

\[
\frac{N}{N_p} = 7.57 + 0.065\left(\frac{X}{S_p}\right)
\]  
(9)

The linear regression for May result is 13.4%. The result for June is displayed as:

\[
\frac{N}{N_p} = 5.892 + 0.107\left(\frac{X}{S_p}\right)
\]  
(10)

The linear regression for June result is 21.52%. The result for July is displayed as:

\[
\frac{N}{N_p} = 4.925 + 0.119\left(\frac{X}{S_p}\right)
\]  
(11)
Figure 2: Extraction of constants from the modified Angstrom model

The linear regression for July result is 26.63%. The result for August is displayed as:

$$\frac{H}{H_p} = 3.937 + 0.213 \left( \frac{x}{X_{ref}} \right)$$

(12)

The linear regression for August result is 58.43%. The result for September is displayed as:

$$\frac{H}{H_p} = 5.901 + 0.998 \left( \frac{x}{X_{ref}} \right)$$

(13)

The linear regression for September result is 20.41%. The result for October is displayed as:

$$\frac{H}{H_p} = 6.865 + 0.063 \left( \frac{x}{X_{ref}} \right)$$

(14)

The linear regression for October result is 9.58%. The result for November is displayed as:

$$\frac{H}{H_p} = 0.391 + 0.039 \left( \frac{x}{X_{ref}} \right)$$

(15)

The linear regression for November result is 4.34%. The result for December is displayed as:

$$\frac{H}{H_p} = 7.068 + 0.054 \left( \frac{x}{X_{ref}} \right)$$

(16)

The linear regression for December result is 6.03%. The average of the twelve months is given as:

$$\frac{H}{H_p} = 6.84 + 0.087 \left( \frac{x}{X_{ref}} \right)$$

(17)

It is observed that August had the highest linear regression. Also, constants ‘a’ and ‘b’ has high variability on a monthly basis. This result is far from the known models discussed in literature [8-12].
4. Conclusion
It was shown that the variability of solar radiation over Lagos is high via the monthly output of constants ‘a’ and ‘b’. This means that the solar PV panel recommended in this location should be have a rigid solar cell that can be flexible to operate in dynamic weather condition as shown in the results of this research. Now solar device companies have a working directory to solve low PV panel lifespan in Lagos Nigeria.

Acknowledgement
The authors appreciate Covenant University for partial sponsorship. The authors acknowledge NASA for primary dataset.

5. References
[1]. Moses E. Emetere, Marvel L. Akinyemi, and Etimbuk B. Edeghe, (2016). A Simple Technique for Sustaining Solar Energy Production in Active Convective Coastal Regions, International Journal of Photoenergy 2016, 3567502, 1-11, http://dx.doi.org/10.1155/2016/3567502
[2]. Emetere M.E., & Akinyemi M.L., (2015) Prospects of Solar Energy in the Coastal Areas of Nigeria, 2015 PIAMSEE: AIP Conference Proceedings, 1705 (1), 020035
[3]. Finelib, (2019). Lagos Alternative Energy Companies, https://www.finelib.com/cities/lagos/business/energy/alternative-energy (Accessed 1/06/2019)
[4]. D.C. Jordan, S.R. Kurtz, (2011). Photovoltaic Degradation Rates-an Analytical Review Progress in Photovoltaics: Research and Applications, doi:10.1002/pip.1182
[5]. Angstrom, “Solar and terrestrial radiation,” Quarterly Journal of the Royal Meteorological Society, vol. 50, no. 210, pp. 121–126, 1924.
[6]. J. K. Page, “The estimation of monthly mean values of daily total short wave radiation on-vertical and inclined surfaces from sun shine records for latitudes 400 N–400 S,” in Proceedings of the United Nations Conference on New Sources of Energy, vol. 98, no. 4, pp. 378–390, 1961.
[7]. J. A. Prescott, “Evaporation from water surface in relation to solar radiation,” Transactions of the Royal Society of South Australia, vol. 64, pp. 114–118, 1940.
[8]. P. C. Jain, “Global irradiation estimation for Italian locations,” Solar and Wind Technology, vol. 3, no. 4, pp. 323–328, 1986.
[9]. M. A. Alsaaad, “Characteristic distribution of global solar radia- tion for Amman, Jordan,” Solar and Wind Technology, vol. 7, no. 2-3, pp. 261–266, 1990.
[10]. S. Jain and P. C. Jain, “A comparison of the Angstrom-type correlations and the estimation of monthly average global irradiation,” Solar Energy, vol. 40, no. 2, pp. 93–98, 1988.
[11]. P. V. C. Luhanga and J. Andringa, “Characteristics of solar radiation at Sebele, Gaborone, Botswana,” Solar Energy, vol. 44, no. 2, pp. 77–81, 1990.
[12]. I. A. Raja and J. W. Twidell, “Distribution of global insolation over Pakistan,” Solar Energy, vol. 44, no. 2, pp. 63–71, 1990.