

Modelling and Simulation of Seasonal Hourly Mean Ambient Temperature at Edo State, Nigeria

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ABSTRACT: A regression-based model for estimating the seasonal hourly mean ambient temperature at Edo State, Nigeria is presented in this work. The modelling is based on Empirical method which is computed using seasonal hourly mean ambient temperature collected from Rubber Research Institute of Nigeria, Iyanomon, for the period (2007-2008) and from this a Gaussian model is proposed. The applicability of the deduced model is analyzed on the basis of three statistical indicators: Coefficient of Correlation (R), Coefficient of Determination (R^2), and Root Mean Square Error ($RMSE$) along with practical comparison of the estimated and observed data. Simulation results are presented and discussed.

KEYWORDS: Ambient temperature; Estimation model, Photovoltaic system, Regression analysis.

I. INTRODUCTION

Ambient temperature is a very important parameter necessary for most ecological models [1]. It serves as input for various photovoltaic systems; therefore, it's very important for renewable energy. The performance of solar-energy system is dependent upon ambient temperature. Ambient temperature has a significant impact on solar photovoltaic as it affects the panel's efficiency. Hence, maintaining an appropriate ambient temperature is crucial to the proper functioning and longevity of the solar photovoltaic systems [2].

The increasing rate of Nigeria's population and the country's insufficient power generation, coupled with the increased yearning for better and stable power supply, has made it necessary for an alternative source of power generation to meet the nation's energy demand. Solar photovoltaic systems are being used in recent times because they are both technically and environmentally viable option [3]. The performance, analysis and evaluation of photovoltaic system building designs require hourly ambient temperature data. Technology and instrument for measuring hourly temperature are very expensive. As such, hourly temperature data is not available in most parts of developing countries including Nigeria. Only the maximum and minimum daily ambient temperature data are measured in the 45 metrological stations in Nigeria [4]. Hence, there is need for an alternative method of estimating hourly temperature data.

Different models for predicting and estimating the ambient temperature have been proposed. Knight *et al.* [5] proposed a model to generate hourly ambient temperature series with the random component included without introducing discontinuities between the last hour of one day and the first hour of the next day. The model enables hourly temperature values to be obtained from an autoregressive method. Erbs [6] proposed a model based on the diurnal variation of the hourly monthly mean air temperature that has a location and month-in-dependent shape when it is standardized by subtracting the mean and dividing by the aptitude. Holland *et al.* [7] studied the effect of neglecting the random component in hourly temperature data for various solar heat system and the results indicated that for some systems, the extra complexities of including the random component of the hourly ambient temperature are unwarranted. Samani [8] modified an original equation which uses maximum and minimum temperature to estimate solar radiation, the modified model allows for correcting the errors associated with indirect meteorological parameter which affects local temperature range. And the proposed model improves the accuracy of estimating solar radiation for temperature.

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The modelling and simulation of temperature-based model for estimating the seasonal hourly mean ambient temperature at Edo State, Nigeria is presented in this work.

II. MATERIALS AND METHODS

The temperature data were obtained from the Rubber Research Institute of Nigeria, Iyanomon; Edo State located at latitude 6.19°N and longitude 5.36° E as shown in Fig. 1. The data consists of the seasonal (dry season) ambient temperature from October 2007 – March 2008. The ambient temperature data were collected through an automated machine which records the ambient temperature reading in every ten minutes (10min). The hourly average measurement is mathematically derived using Excel worksheet.



Fig. 1 Map of study location in the continent [9]

MATLAB curve fitting tool is applied to the data collected to deduce an empirical relationship between the mean hourly and normalized daily ambient temperature as follows:

$$T_{h(t)} = T_d \times \left(0.43 * \exp \left\{ - \left(\frac{t - 0.90}{0.14} \right)^2 \right\} + 0.25 * \exp \left\{ - \left(\frac{t - 0.48}{0.001} \right)^2 \right\} \right. \\ \left. + 1.2 * \exp \left\{ - \left(\frac{t - 0.53}{0.34} \right)^2 \right\} + 0.74 * \exp \left\{ - \left(\frac{t - 0.02}{0.25} \right)^2 \right\} \right) \quad (1)$$

$$T_d = \frac{T_{\max} + T_{\min}}{2} \quad (2)$$

where t is the time in hours, $T_{h(t)}$ is the hourly mean ambient temperature in °C, T_d is the mean daily temperature, °C, T_{\max} is the maximum daily temperature in °C and T_{\min} is the minimum daily temperature in °C.

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In other to validate the developed model of (1) sample measurement of hourly ambient temperature were taken at Ekpoma (latitude 6.45⁰N and longitude 6.08⁰E), Edo State using the thermo-anemometer. Analysis was performed on the proposed model using measured data. The performance was evaluated using the correlation coefficient (R), coefficient of determination (R²) and Root Mean Square Error (RMSE). These indicators are known tools for analysing data with good accuracy [1, 4]. Detailed analysis of R, R² and RMSE is given in the literature [4]. The analysis of results is presented and discussed in the following section.

III. RESULTS AND DISCUSSION

Table 1 shows the statistical analysis of estimated (based on the proposed model of equation (1)) values of the average hourly ambient temperature at Edo State using measured average hourly dataset. A comparison of the observed and simulated seasonal hourly ambient temperature during the dry season (October 2007 – March 2008) is shown in Fig. 2.

Table 1. Result of statistical analysis on proposed model based on measured data.

Model	Regression analysis		Error term
	R	R ²	RMSE (°C)
Equation (1)	0.9972	0.9945	0.3899

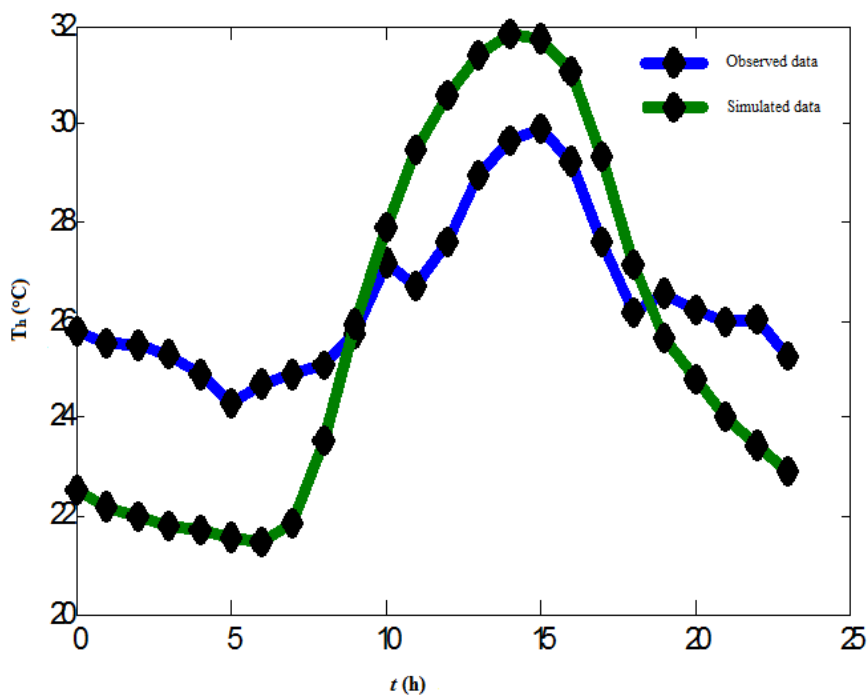


Fig 2. Comparison of simulated and observed values of the seasonal hourly mean ambient temperature for area understudy

The *R*-value defines the linear relationship between the observed and estimated values of the hourly ambient temperature. The *R*² statistic gives the percentage variation of the dependent variable in connection with the explanatory (independent) variables while the *RMSE* is a common error terms often used in comparing models. For better data modelling, the error indicator should be closer to zero, but *R* and *R*² should approach unity as closely as possible [10]. As observed (Table 1) the high values of the correlation coefficient (*R* = 0.9972) and coefficient of determination (*R*² = 0.9945) shows a good predictive ability of the proposed model (Equation (1)). However, the *RMSE* value of 0.3899 °C

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can be considered to be significant. It's pertinent to note that the automated system measurement is more accurate than the manual measurement. The performance of the proposed model can be improved by the inclusion of additional parameters. In this study, other parameters are not considered as it is intended to establish a simple and accurate means of estimating the seasonal hourly mean ambient temperature at Edo State of Nigeria.

The standard practice for estimation of average daily ambient temperature would be true if the hourly mean ambient temperature profile were smooth and symmetrical, which is not true. For instance, the increase in temperature, in the morning, is steeper than its decrease in the afternoon and at night [11]. Thus, the proposed model can also be used for the prediction of average daily ambient temperature.

IV. CONCLUSION

An empirical model for estimating the seasonal hourly ambient temperature at Edo State, Nigeria is developed. The model was deduced based on regression techniques using a two-year (2007 – 2008) seasonal hourly average ambient temperature data collected from the Rubber Research Institute, Iyanom. From the engineering point of view, results of the proposed model are statistically significant. The result suggests that the proposed regression model can be used for estimating hourly ambient temperature at Edo State. The method also can be applied to other areas with the determination of new Empirical constants.

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