Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 2458-9403
Vol. 6 Issue 8, August - 2019

Artificial Neural Network-Based Modeling And Load Forecasting Of Residential Electricity Consumption In Nigeria

Peter Dan Abip
Department of Electrical/Electronic and Computer Engineering, University of Uyo, AkwaIbom, Nigeria

Kalu Constance
Department of Electrical/Electronic and Computer Engineering, University of Uyo, AkwaIbom, Nigeria

Ogbonna Chima Otumdi
Department of Electrical/Electronic and Computer Engineering, University of Uyo, AkwaIbom, Nigeria

***Abstract*— In this paper, artificial neural network-based modeling and load forecasting of residential electricity consumption in Nigeria is presented. The modeling was based on 46 years data on residential electricity consumption and the explanatory variables which are the population, rainfall and temperature. MATHLAB software was used for the model development and simulation. About 70 % of the data were used for the model development , 15 % of the data was used for the model validation during the training and also 15 % of the data was used for the model testing after the training was completed. The model prediction performance was compared with those of two other quadratic regression models, namely, the quadratic regression model without interactions and the quadratic regression model with interaction. The results showed that the quadratic regression with interaction has R-square value of 0.7289 (72.89%), sum of squared errors of prediction (SSE) of 1051200 and root mean squared error (RMSE) of 151.1664. The quadratic regression model without interaction has R-square value of 0.7265 (72.65%), SSE of 1060100 and RMSE of 151.8083. The ANN model has R-square value of 0.9807 (98.07%), SSE of 175020 and RMSE of 61.6833 which was the best when compared with the other two regression models. So, the ANN model was used to forecast the residential electricity consumption in Nigeria up to the year 2025. The results showed that between 2016 and 2025, the highest residential energy consumption will occur in 2023 with a value of 838.1254MW/h. These information are essential for planning of residential energy supply in Nigeria in the coming years.**

Keywords*— Residential Electricity Consumption, Artificial Neural Network, Explanatory Variables, Quadratic Regression Model

I. INTRODUCTION

Over the years, electric supply in Nigeria has been grossly inadequate to meet the demand from the various categories of consumers [1,2,3,4,5,6]. This has posed a running challenge to the residential electric energy consumers who mostly rely on firewood, fossil fuel and other alternative sources of energy to meet their energy needs [7,8,9,10,11]. In response, the Federal government of Nigeria has made several moves to boost the energy supply across the country. Some policy measures have been enacted and implemented and also infrastructural upgrades have also been carried out. In any case, the residential energy consumers are still in dare need of adequate electric energy supply. To this end, modeling and accurate forecasting of the annual residential energy demand in Nigeria is required for effective planning of the energy supply to the residential energy consumers [12,13,14,15].

Accordingly, two separate but related works on the modeling and forecasting of residential energy demand in Nigeria were studied [16,17]. In the first one, a 9-years data on residential energy demand was used to develop two regression models, namely, the quadratic regression model with interaction had better prediction than the multiple linear regression model [16]. The results showed very high prediction performance. However, when models are subjected to long term (46-years) data their predictions significantly dropped. Similarly, the second study by the same authors used 8-years data to develop another two regression models, namely, quadratic regression model without interaction and multiple linear regressions with one period l lagged dependent variable [17]. The models also gave very high prediction performance when the short term data was used. However, when the 46-years data was applied, the prediction performance of the two models also dropped significantly. Consequently, given that the 4 regression models are not effective in modeling the annual residential energy demand, an artificial neural network (ANN) model is adopted in this paper for the modeling and forecasting of the annual residential energy demand in Nigeria.

The ANN model training and validation are performed using MATHLAB program. The prediction performance of the ANN model is compare with those of the regression models in the two cited published works [16,17]. Eventually, the ANN model was used to forecast the annual residential energy demand in Nigeria from 2018 to 2030.

II. METHODOLOGY

A. *Development Of The Artificial Neural Network (ANN)* Model

The artificial neural network (ANN) system used in this paper is based on the back propagation LevenbergMacquart network. The inputs for the ANN model are time, population, rainfall and temperature. The model training, validation and testing were done using the ANN toolbox in MATLAB software. The prediction performance of the ANN model is compared with those of two other regression models which were used in predicting the residential energy consumption of Nigeria. Specifically, the regression models considered are the quadratic regression model without interactions which was used in [16] and the quadratic regression model with interaction which was used in [17]. The procedure used in the study is summarized in the flowchart of Figure 1.

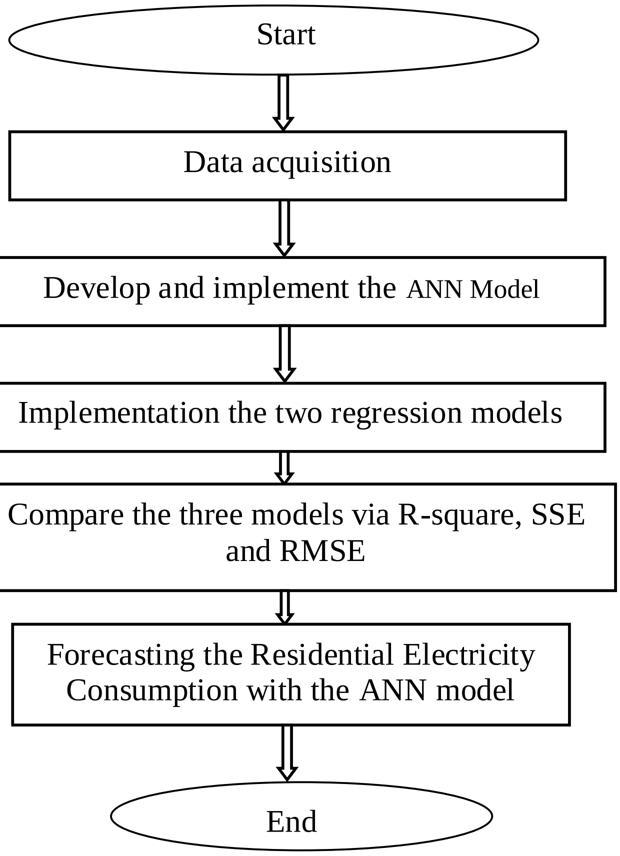

Figure 1: The flowchart for the procedure used in the study

In the Mathlab ANN toolbox, (Figure 2), the inputs consisting of the temperature, rainfall, time, population and connectivity were sent to the input key and the target being the actual values of residential electricity consumption are sent to the targets key. As shown in Figure 3, about 70% of the data was used for the ANN model training, 15 % was used for model validation during the training process and another 15 % was for testing the ANN model after thr training was completed. The ANN architecture is shown in Figure 4. According to Figure 4, about 20 hidden neurons were used. Each of the hidden neurons had the log-sigmoid model which is given as;

$$\text{logsig}(n) = \frac{1}{1+e^{-n}} \qquad (1)$$

After the model training, the output of the network was compared with the targets and the weights and bias were adjusted to obtain an output close or equal to the targets. The process was repeated automatically until acceptable model prediction performance is achieved.

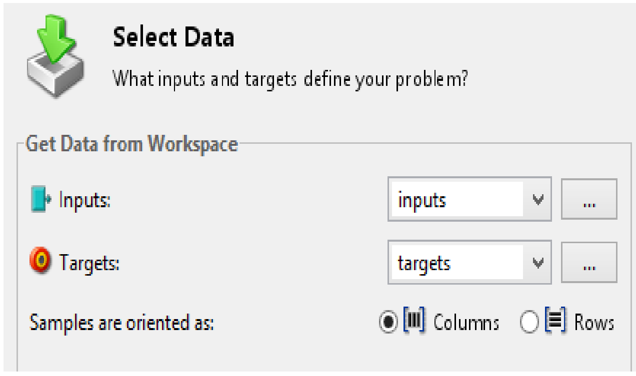

Figure 2: The MATLAB ANN toolbox input data and target data dialogue box

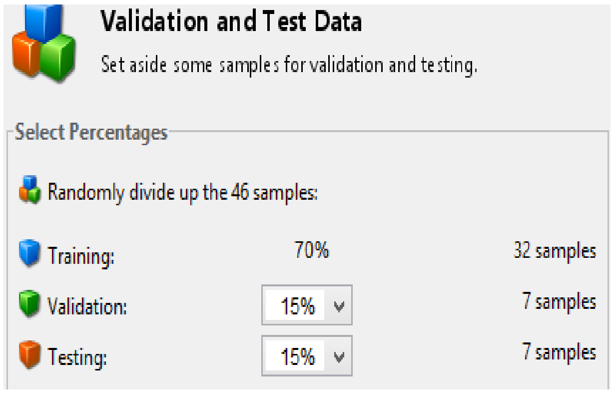

Figure 3: Percentage of the data used for training, testing and validation

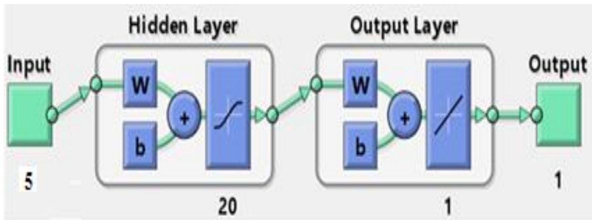

Figure 4: Specifying the number of hidden neurons.

B.Data source and Data Normalization

The study is based on a 46 year (1970 to 2015) Nigerian residential energy consumption dataset and explanatory variables (population, rainfall and temperature) obtained from Central Bank of Nigeria Statistical Bulletin and from the bulletin of the National Bureau of Statistics. In order to use the dataset in the

Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 2458-9403
Vol. 6 Issue 8, August - 2019

ANN model development, the explanatory variables and the actual residential energy consumption data were normalized with the formula given as;

$$\mathbf{X}_{norm(i)} = \frac{\mathbf{X}_{(i)}}{\mathbf{X}_{max}} \quad \textbf{(2)}$$

Where X_{max} is the maximum value of the data of the variable considered, $X_{(i)}$ is the variable data i and$X_{norm(i)}$ is the normalized data for variable data i. The normalization keeps the value of each variable between 0 and 1 or between 0 and -1.

C. The Regression Models

The quadratic regression model with interaction terms defines the residential electricity demand, E_t as follows;

$$\mathbf{E_t} = 431.645 + 54.542\mathbf{P_t} + 10.412\mathbf{T_t} - \mathbf{3.187}\mathbf{P_t}^2 + 1.815\mathbf{T_t}^2 + 0.451\mathbf{P_t}\mathbf{T_t} \quad \textbf{(3)}$$

The quadratic regression model without interaction defines the residential electricity consumption, E_t as follows;

$$\mathbf{E_t} = 162.312 + 42.11\mathbf{P_t} + 5.2133\mathbf{T_t} - \mathbf{1.092}\mathbf{P_t}^2 + 0.612\mathbf{T_t}^2 \quad \textbf{(4)}$$

III. RESULTS AND DISCUSSION

The plot of the explanatory variables is given in Figure 5. The actual residential energy consumption and the model predicted values are plotted in Figure 6 for the with ANN mode ,the quadratic regression model without interactions and the quadratic regression model without interactions.

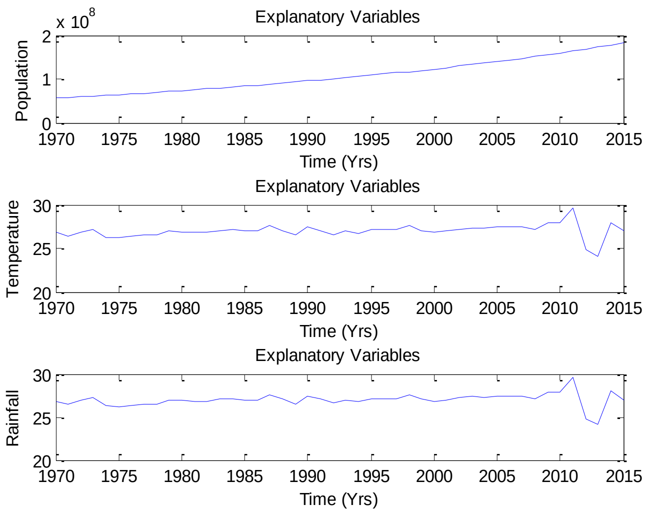

Figure 5: The plot of the explanatory variables

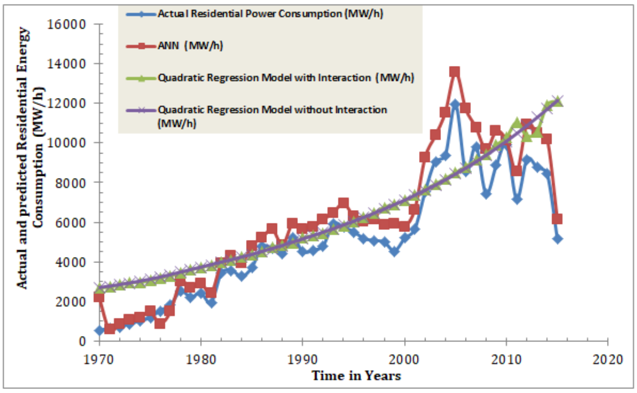

Figure 6 :The actual residential energy consumption and the model predicted values

The quadratic regression with interaction has R-square value of 0.7289 (72.89%), SSE of 1051200 and RMSE of 151.1664. The quadratic regression model without interaction has R-square value of 0.7265 (72.65%), SSE of 1060100 and RMSE of 151.8083. The ANN model has R-square value of 0.9807 (98.07%), SSE of 175020 and RMSE of 61.6833 which was the best when compared with the other two regression models. So, the ANN model was used to forecast the residential electricity consumption in Nigeria up to the year 2025, as shown in Table 1 and Figure 7. The results in Figure 7 and Table 1 show that the highest residential energy that will occur in 2023 with a value of 838.1254MW/h.

Table 1: Residential energy consumption forecast using the ANN model

Time (yrs)	Residential energy Consumption (MW/h)
2016	653.335
2017	679.369
2018	770.022
2019	581.72
2020	823.124
2021	776.857
2022	656.764
2023	838.125
2024	662.271
2025	722.966

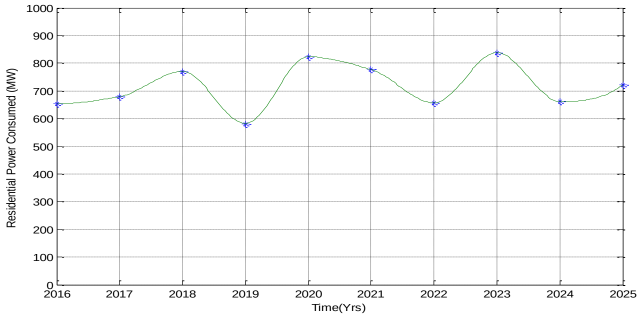

Figure 7: Graph showing the ANN forecasted residential energy consumption w.r.t.

IV. CONCLUSION

The modeling of the residential energy consumption in Nigeria using the artificial neural network (ANN) is presented. The analysis is based on about 46 years data on the residential energy consumption in Nigeria along with the data on the explanatory variables which consist of the population, rainfall and temperature. The prediction performance of the ANN model was compared to those of two other regression models, namely, the quadratic regression model without interactions and the quadratic regression model with interaction. The results showed that among the three models, the ANN has the best prediction performance. As such , the ANN model was then used to forecast the annual residential energy consumption in Nigeria up to the year 2025.

REFERENCE

1. **R** Olaniyan, K., McLellan, B., Ogata, S., &Tezuka, T. (2018). Estimating residential electricity consumption in Nigeria to support energy transitions. *Sustainability*, *10*(5), 1440.

2. Abanihi, V. K., Ikheloa, S. O., &Okodede, F. (2018). Overview of the Nigerian Power Sector. *American Journal of Engineering Research (AJER)*, *7*, 253-263.

3. Oyedepo, S. O. (2012). Energy and sustainable development in Nigeria: the way forward. *Energy, Sustainability and Society*, *2*(1), 15.

4. Makinde, O. O. (2014). Housing delivery system, need and demand. *Environment, Development and Sustainability*, *16*(1), 49-69.

5. Ebhota, W. S., &Tabakov, P. Y. (2018). Power Inadequacy, the Thorn in Economic Growth of Nigeria. *International Journal of Applied Engineering Research*, *13*(16), 12602-12610.

6. Usman, A. (2013). Determinants of Electricity Consumers Satisfaction in Selected Electricity Distribution Zones in Nigeria: Implications for Regulatory Activities. *Journal of Asian Business Strategy*, *3*(6), 103.

7. Osueke, C. O., &Ezugwu, C. A. K. (2011). Study of Nigeria Energy resources and its consumption. *International Journal of Scientific & Engineering Research*, *2*(12), 121-130.

8. Oyedepo, S. O. (2012). Energy and sustainable development in Nigeria: the way forward. *Energy, Sustainability and Society*, *2*(1), 15.

9. Oyedepo, S. O. (2012). On energy for sustainable development in Nigeria. *Renewable and sustainable energy reviews*, *16*(5), 2583-2598.

10. Ezugwu, C. N. (2015). Renewable Energy Resources in Nigeria: Sources, Problems and Prospects. *Journal of Clean Energy Technologies*, *3*(1), 68-71.

11. Oyedepo, S. O. (2014). Towards achieving energy for sustainable development in Nigeria. *Renewable and sustainable energy reviews*, *34*, 255-272.

12. Ezenugu, I. A., Nwokonko, S. C., &Markson, I. (2017). Modelling and Forecasting of Residential Electricity Consumption in Nigeria Using Multiple and Quadratic Regression Models. *American Journal of Software Engineering and Applications*, *6*(3), 99.

13. Olaniyan, K., McLellan, B., Ogata, S., &Tezuka, T. (2018). Estimating residential electricity consumption in Nigeria to support energy transitions. *Sustainability*, *10*(5), 1440.

14. Sambo, A. S. (2008). Matching electricity supply with demand in Nigeria. *International Association of Energy Economics*, *4*, 32-36.

15. Keirstead, J., Jennings, M., &Sivakumar, A. (2012). A review of urban energy system models: Approaches, challenges and opportunities. *Renewable and Sustainable Energy Reviews*, *16*(6), 3847-3866.

16. Ezenugu, I. A., Nwokonko, S. C., &Markson, I. (2017). Modelling and Forecasting of Residential Electricity Consumption in Nigeria Using Multiple Linear Regression Model and Quadratic Regression Model with Interactions. *Mathematical and Software Engineering*, *3*(2), 173-182.

17. Isaac AmazuiloEzenugu, SwintonChisomNwokonko and IdorenyinMarkson (2017) Modelling and Forecasting of Residential Electricity Consumption in Nigeria Using Multiple and Quadratic Regression Models *American Journal of Software Engineering and Applications* Volume 6, Issue 3, June 2017, Pages: 99-104