Comparative Analysis for Prediction of Electrical Power Demand of Bayelsa State (Nigeria) by Year 2025

D. C. Idoniboyeobu[1*] and R. J. Idumangi[1]

[1]*Department of Electrical Engineering, Rivers State University of Science and Technology Nkpolu, Port Harcourt, Nigeria.*

Authors' contributions

This work was carried out in collaboration between all authors. Author DCI designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript and managed literature searches. Authors DCI and RJI managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

ABSTRACT

This work predicts the peak electrical load demand consumption of Bayelsa State by the year 2025. The data of electrical load allocation and utilization of power consumption of the State in the past five (5) years (2006-2010) were extracted from control room log sheets of Power Holding Company of Nigeria (PHCN) and Kolo Creek Gas Turbine Power Station (Glory Power Company Ltd) for the comparative analysis. Population growth rate for the state as well as Master plan by the Capital City Development Authority were also used. The loads for the analysis were divided into the following categories: domestic, commercial, industrial and electrical load consumed by government agencies. Various improved engineering analysis models and applications including calculations, diagrams and graphs were reviewed and applied to justify the study; the Study

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Corresponding author: E-mail: dikioidoniboye@yahoo.com;

revealed that Second-Order Polynomial Model gives the best fit because it gives the least error of 0.66 and provides a good approximation to the shape of $f(x)$ function which describes the trend of the electrical power demand distribution in Bayelsa State.

Keywords: Prediction; electrical load; power demand; improved estimate method.

1. INTRODUCTION

Electrical load is the power that an electrical utility needs to supply in order to meet the demands of its customers. It is therefore very important to the utilities to have advance knowledge of their electrical load so that they may ensure that this load is met and interruptions are minimized to their services; this will avert an unstable power system normally created when power demand exceeds supply. This will be possible if we know the expected peak load demand in each hour of the day, each day of the week, each week of the month, each month of the year and each year of the period under investigation. Prediction is the act of making known before-hand and foretelling what will happen in the future [1]. Bayelsa state which is located in the Southern Niger Delta of Nigeria has a difficult mangrove terrain with a rural setting. This generates a lot of problems in effective power distribution to end-users. The state has a growth rate of 2.9% [2] and an expected population of 3.517million in 2025.

Several methods have been used in the past to predict electrical load. Leonardo et al. [3] studied the electricity load behaviour in Brazil. They adopted a Generalized Long Memory to model seasonal behaviour of the load. Their model involves statistical linear methods. Bhardwaj et al. [4] in their work employed key energy indicators to predict the load demand by kaval cities in India by year 2023 using mean temperature and population growth rate of the cities as dependent variables. They also analyzed the electricity power demand of Lucknow City [5]. Artificial Neural Network (ANNs), a 3-layer network has been used in the past [6] to carry out short-term forecast of load demand in the Nigerian Electrical system. Peng [7] also used this method with deficit management to carry out load forecasting. Bayasian Statistical Technique on dynamic linear model has also been used [8] to predict residential electricity consumption of a rapidly developing industrial nation. The Bayesian Statistical Technique has the flexibility to solve multi-dimensional time-series models and update estimated parameters as demand changes over time.

Fuzzy back propagation network has been used to predict short term electric load. This involves using an algorithm that is capable of predicting information and fluctuating data patterns. Forecast errors can be evaluated using Mean Absolute Percentage Error (MAPE). The importance of Mean Absolute Percentage Error was cited by Park [9] and Rajasenkaran [10], because it measures proportionality between error and load. The least square model was used by Odubo [11] to forecast electrical load in Bayelsa state by year 2020. This method gives good result although it doesn't take into account variation in load demand due to industrialization and population increase.

Bayelsa State was created on 1st October, 1996 and the only source of Electric Power is 2x20MW gas turbine plant installed in 1988. The transmission and distribution system of the state is that of a rural setting until 2005 when industries started being constructed and the state. Only the state capital (Yenagoa) has been connected to the Nigerian National grid in 2006. In this work, several methods of load prediction shall be briefly examined and compared with the Second-Order Polynomial model as applied to Bayelsa State.

2. SIGNIFICANCE OF THE RESEARCH

The results of this research shall be beneficial to the operators of the Bayelsa State power system (Glory Power Company Ltd) and the Power Holding Company of Nigeria Ltd in the following areas:

a. Generation: The Electric Power Companies and Bayelsa State Government are expected to have adequate generating resource capacity for the several years ahead.
b. Transmission and distribution infrastructure upgrade and expansion.
c. To plan for the economic impact assessment of Bayelsa State by the State Government.

3. MATERIALS AND METHODS

The research methodology involved data collection and analysis. The data collection was carried out as follows:

> ➢ Collection of data from actual plant operating log sheets from January 2006 to December 2010 from Kolo Creek power Station and control log sheets from Power Holding Company of Nigeria Ltd (PHCN)
> ➢ Simulation of parameters (a_0, a_1, a_2), that will be needed for the research which cannot be directly extracted from the log sheets. a_0, a_1, a_2 are the population growth rate, effect of temperature (weather condition) and price of electricity respectively.
> ➢ Computing the mean values of daily parameters using statistical methods.
> ➢ Monthly average and overall average for the period the research was carried out.
> ➢ Extraction of data from Yenagoa City Master Plan [12].

4. THEORETICAL ANALYSIS

In this work data which comprised of hourly electricity load demand from the area covered by the utilities from January 2006 to December 2010 shall be used. Power generation data from the Bayelsa Ministry of Power [13] shall also be used. A variety of models and methods were employed in the study; in particular, Numerical Methods, Linear Statistical Methods were adopted in this research. The errors in each of the methods were evaluated and the model and method with the least error was accepted as the best for the forecast.

5. LEAST SQUARE METHOD

The least square method can be used in approximating the relationship between two variables using polynomial of any degree; and in this research since the study involves the forecast between two variables (Load and Time), the method of least square will give a good approximation as shown in Fig. 1.

In the standard formulation, a set of N pair of observation $\{Y, X\}$ were used to find a function given the value of the dependent variable (Y) from the values and an independent variable (X) with one variable and a linear function, the prediction is given by the following equation:

$$\hat{Y} = a + bX \tag{1}$$

This equation involves two free parameters, which specify the intercept (a) and the slope (b) of the regression line. The least square method defines the estimate of these parameters as the values which minimize the sum of the squares (hence the name least squares) between the measurements and the model (i.e., the predicted values). This amounts to minimizing the expression:

$$\varepsilon = \sum_i \left(Y - \hat{Y}_i \right) = \sum_i \left[Y_i - \left(a + bX \right) \right]^2 \tag{2}$$
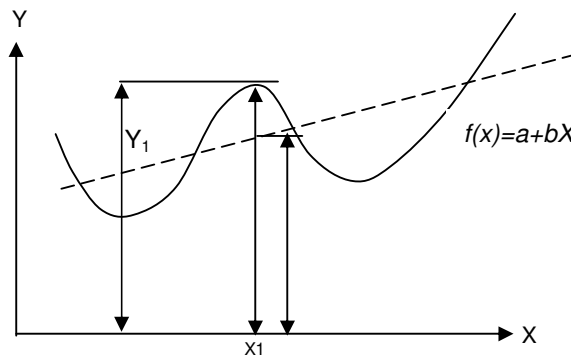

Fig. 1. Fitting a curve with an approximate line

where ε is the "error" quantity to be minimized.

Taking the derivative of ε with respect to a and b and setting them to zero gives the following set of equation (called the normal equation):

$$\frac{\partial \varepsilon}{\partial a} = 2a + 2b \sum X_i - 2 \sum Y_i = 0 \qquad (3)$$

$$\frac{\partial \varepsilon}{\partial b} = 2b \sum X_i^2 + 2a \sum X_i - 2 \sum Y_i X_i = 0 \quad (4)$$

Solving (3) and (4) simultaneously, we get the estimates of a and b as:

$$a = M_Y - b M_X$$

(with M_Y and M_X representing the means of X and Y) and

$$b = \frac{\sum (Y_i - M_Y)(X_i - M_x)}{\sum (X_i - M_x)} \qquad (5)$$

The method of least squares can be extended to more than one independent variable (using matrix algebra) as stated below:

$$\begin{bmatrix} n & \sum X_i & \sum X_i^2 & \sum X_i^3 & \dots & \sum X_i^n \\ \sum X_i & \sum X_i^2 & \sum X_i^3 & \sum X_i^4 & \dots & \sum X_i^{n+1} \\ \sum X_i^2 & \sum X_i^3 & \sum X_i^4 & \sum X_i^5 & \dots & \sum X_i^{n+2} \\ \sum X_i^3 & \sum X_i^4 & \sum X_i^5 & \sum X_i^6 & \dots & \sum X_1^{n+3} \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \sum X_i^n & \sum X_i^{n+1} & \sum X_1^{n+2} & \sum X_i^{n+3} & \dots & \sum X_i^{n+n} \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \\ a_3 \\ \cdot \\ a_n \end{bmatrix} = \begin{bmatrix} \sum Y_i \\ \sum Y_i X_i \\ \sum Y_i X_i^2 \\ \sum Y_i X_i^3 \\ \cdot \\ \sum Y_i X_i^n \end{bmatrix}$$

However, the research will be limited to a 2×2 matrix since the forecast is a relationship between load and time. For a 2×2 matrix, the following expression will be employed:

$$\begin{bmatrix} n & \sum X_i \\ \sum X_i & \sum X_i^2 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \end{bmatrix} = \begin{bmatrix} \sum Y_0 \\ \sum Y_i X_i \end{bmatrix} \qquad (6)$$

and using Crammer's rule we obtain;

$$a_0 = \frac{\sum Y_i \sum X_i^2 - \left(\sum X_i \sum Y_i X_i \right)}{n \sum X_i^2 - \left(\sum X_i \right)^2} \qquad (7)$$

$$a_1 = \frac{n \sum Y_i X_i - \sum X_i \sum Y_i}{n \sum X_i^2 - \left(\sum X_i \right)^2} \qquad (8)$$

The results using the least square method shows that power demand by Bayelsa State in 2025 is 77.11 MW. The method also gives an error of 8.14MW (indicating the extent with which the forecast values differ from the real values). Table 1 shows the forecast values for Bayelsa State using least square method while Table 2 shows the error values for this method.

The results of these test calculations show that Least Square Method can be very efficient if it is used in an appropriate way, however several reasons are responsible for the high error experienced using the least square method; outliers, which are significantly bad observations, can skew the results because they have more impact. This impact is because the square of a number grows large, faster than the number. It is better to reject the outliers using some other method prior to using least squares on the remaining data. Of course, this must be substantiated because rejecting data otherwise is bad practice. It is also attributed to the choice of starting values. Fig. 2 shows the predicted and actual values of Electricity Demand for Bayelsa State using Least square method.

Table 1. Forecast values for least square method

Year (x)	y_x (MW)	x^2	xy
2006	37.32	4024036	74863.92
2007	39.36	4028049	78995.52
2008	40.32	4032064	80962.56
2009	42.62	4036081	85623.58
2010	48.51	4040100	97505.10
$\Sigma x = 10040$	$\Sigma y = 208.13$	$\Sigma x^2 = 20160330$	$\Sigma xy = 417950.68$

Note: y_x is the Actual peak load demand and x is the year under study

Table 2. Error values for least square method

x	y_x (MW)	y_P (MW)	Error (e)	e^2
2006	37.32	28.47	8.85	78.32
2007	39.36	31.03	8.33	69.39
2008	40.32	33.59	6.73	45.29
2009	42.62	36.15	6.47	41.86
2010	48.51	38.71	9.80	96.04
				$S_r = 330.90$
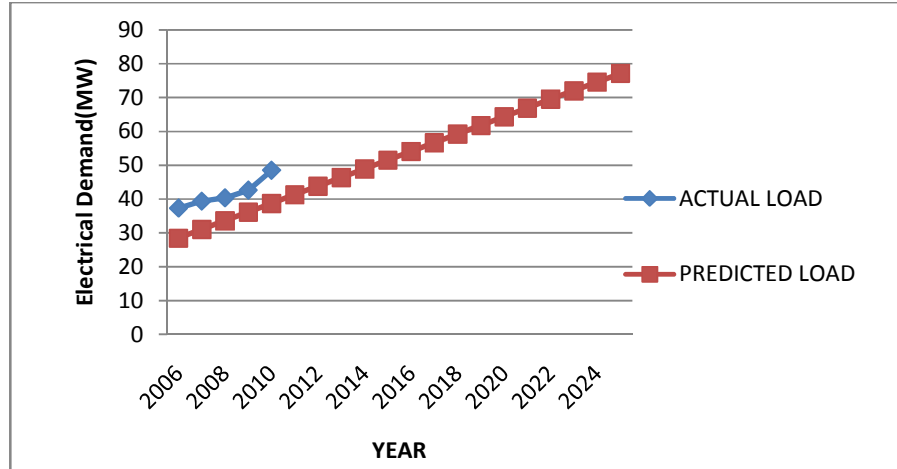
Fig. 2. Least square method results

6. LAGRANGE INTERPOLATION

Assuming the existence of a set of data points (x_i, y_i), $i = 0,1,...,n$ obtained from a function $f(x)$ so that $y_i = f(x_i), i = 0,1,...n$, a suitable function for interpolation $I(x)$ is expressible as;

$$I(x) = \sum_{i=0}^{n} L_i(x).f(x_i) \qquad (9)$$

$$I(x) = L_0(x).f(x_0) + L_1(x).f(x_1) + ... + L_n(x).f(x_n) \qquad (10)$$

The function $L_i(x), x = 0,1...,n$ are chosen to satisfy;

$$L_i(x) = \begin{cases} 0 & x = x_0, x_1,...,x_{i-1}, x_{i+1},...,x_n \\ 1 & x = x_i \end{cases} \qquad (11)$$

Suppose we have four data points, $[x_i, f(x_i)], i = 0,1,2,3$; from equation 9 with $n = 3$ the interpolating function $I(x)$;

$$I(x) = \sum_{i=0}^{n} L_i(x).f(x_i) \qquad (12)$$

Evaluating $I(x)$ at the four data points x_0, x_1, x_2, x_3 we have;

$$I(x_0) = L_0(x_0).f(x_0) + L_1(x_0).f(x_1) + L_2(x_0).f(x_2) + L_3(x_0).f(x_3) \qquad (13)$$

$$I(x_1) = L_0(x_1).f(x_0) + L_1(x_1).f(x_1) + L_2(x_1).f(x_2) + L_3(x_1).f(x_3) \qquad (14)$$

$$I(x_2) = L_0(x_2).f(x_0) + L_1(x_2).f(x_1) + L_2(x_2).f(x_2) + L_3(x_2).f(x_3) \qquad (15)$$

$$I(x_3) = L_0(x_3).f(x_0) + L_1(x_3).f(x_1) + L_2(x_3).f(x_2) + L_3(x_3).f(x_3) \qquad (16)$$

From equation, 11 $L_0(x_0) = 1$ and $L_1(x_0) = L_2(x_0) = L_3(x_0) = 0$

Hence equation 12 is simplified as follows:

$$I(x_0)=L_0(x_0).f(x_0)+L_1(x_0).f(x_1)+L_2(x_0).f(x_2)+L_3(x_0).f(x_3)$$

$$=1.f(x_0)+0.f(x_1)+0.f(x_2)+0.f(x_3)$$

$$= f(x_0)$$

By the same reasoning, $I(x_1) = f(x_1), I(x_2) = f(x_2)$ and $I(x_3) = f(x_3)$ which means the interpolating function $I(x)$ passes through the given set of data points.

The analytical form of $I(x)$ depends on the function $L_i(x), i = 0, 1, ..., n$ that satisfies equation 11 and are called Lagrange coefficient polynomials defined as follows:

$$L_i(x) = \prod_{j=0,1,...,i-1,i+1,...n} \left(\frac{x - x_j}{x_i - x_j} \right) i = 0,1,2,3,...n \quad (17)$$

For a four-data point $(n = 3)$ $L_1(x)$ through $L_3(x)$ can be expressed as follows:

$$i = 0, \ L_0(x) = \frac{(x - x_1)(x - x_2)(x - x_3)}{(x_0 - x_1)(x_0 - x_2)(x_0 - x_3)} \quad (18)$$

$$i = 1, \ L_1(x) = \frac{(x - x_0)(x - x_2)(x - x_3)}{(x_1 - x_0)(x_1 - x_2)(x_1 - x_3)} \quad (19)$$

$$i = 2, \ L_2(x) = \frac{(x - x_0)(x - x_1)(x - x_3)}{(x_2 - x_0)(x_2 - x_1)(x_2 - x_3)} \quad (20)$$

$$i = 3, \ L_3(x) = \frac{(x - x_0)(x - x_1)(x - x_2)}{(x_3 - x_0)(x_3 - x_1)(x_3 - x_2)} \quad (21)$$

However, this research is limited to two data points' model as shown below:

$$P_{(x)} = \left(\frac{x - x_1}{x_0 - x_1} \right) f(x_0) + \left(\frac{x - x_0}{x_1 - x_0} \right) f(x_1) \quad (22)$$

The results using Lagrange Interpolation shows that power demand by Bayelsa State in 2025 is 76.08 MW. The method gives an error of 1.48, indicating the deviation of forecast values from the real values using the method. Table 3 shows error values using Lagrange method.

In comparison with other methods, the Lagrange Interpolation models is a simplicity, that is, it can be determined without solving a system of simultaneous equations or performing repetitive calculations as in the case of some of the methods hence the results are acceptable. However, the error between the real and interpolated values might be as a result of the few data points used in the analysis, the more the data points the less the error. Fig. 3 shows the predicted and actual values of Electricity Demand for Bayelsa State using Lagrange model.

Table 3. Error values for lagrange method

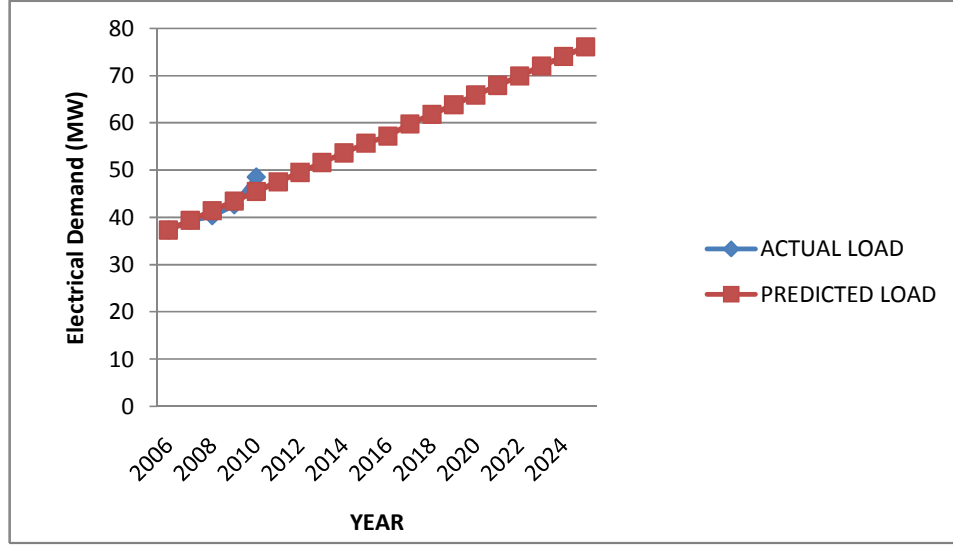| x	y_x (MW)	y_P (MW)	Error (e)	e^2
1	37.32	37.32	0	0
2	39.36	39.36	0	0
3	40.32	41.40	-1.08	1.17
4	42.62	43.44	-0.82	0.67
5	48.51	45.48	3.03	9.18
				$S_r = 11.02$

Fig. 3. Lagrange interpolation method results

7. SECOND-ORDER POLYNOMIAL

Assuming a polynomial of second-order degree, say

$$y = a_0 + a_1 x + a_2 x^2 \tag{23}$$

As with a linear fit, the concept of "best fit" requires a definition of some measure of the error between the data and the fit curve. The functional form of error is simple generalization of the linear error function;

Error =

$$\in (a_0, a_1, a_2) = \sum_{i=1}^{n} (a_0 + a_1 x + a_2 x^2 - y_i)^2 \tag{24}$$

The minimum error is at the partial derivative of the error function with respect to coefficients are all zero. Hence the equation resulting from evaluating the partial derivatives with respect to a_0;

$$\frac{\partial \in}{\partial a_0} = \sum_{i=1}^{n} 2(a_0 + a_1 x_i + a_2 x_i^2 - y_i)$$

$$2 \left[n a_0 + a_1 \sum_{i=1}^{n} x_i + a_2 \sum_{i=1}^{n} x_i^2 - \sum_{i=1}^{n} y_i \right] = 0$$

Dividing both sides by 2 and rearranging we get:

$$n a_0 + \left[\sum_{i=1}^{n} x_i \right] a_1 + \left[\sum_{i=1}^{n} x_i^2 \right] a_2 = \sum_{i=1}^{n} y_i \tag{25}$$

For the partial derivative of a_1 we have;

$$\frac{\partial \in}{\partial a_1} = \sum_{i=1}^{n} 2(a_0 + a_1 x_i + a_2 x_i^2 - y_i) x_i$$

$$2 \left[a_0 \sum_{i=1}^{n} x_i + a_1 \sum_{i=1}^{n} x_i^2 + a_2 \sum_{i=1}^{n} x_i^2 - \sum_{i=1}^{n} x_i y_i \right] = 0$$

Dividing both sides by 2 and rearranging we get:

$$\left[\sum_{i=1}^{n} x_i \right] a_0 + \left[\sum_{i=1}^{n} x_i^2 \right] a_1 + \left[\sum_{i=1}^{n} x_i^3 \right] a_2 = \sum_{i=1}^{n} x_i y_i \tag{26}$$

For the partial derivative of a_2 we get;

$$\frac{\partial \in}{\partial a_1} = \sum_{i=1}^{n} 2(a_0 + a_1 x_i + a_2 x_i^2 - y_i) x_i^2$$

$$2 \left[a_0 \sum_{i=1}^{n} x_i^2 + a_1 \sum_{i=1}^{n} x_i^3 + a_2 \sum_{i=1}^{n} x_i^4 - \sum_{i=1}^{n} x_i^2 y_i \right] = 0$$

Dividing both sides by 2 and rearranging we get:

$$\left[\sum_{i=1}^{n} x_i^2 \right] a_0 + \left[\sum_{i=1}^{n} x_i^3 \right] a_1 + \left[\sum_{i=1}^{n} x_i^4 \right] a_2 = \sum_{i=1}^{n} x_i^2 y_i \tag{27}$$

And in matrix form we have;

$$\begin{bmatrix} n & \sum_{i=1}^{n} x_i & \sum_{i=1}^{n} x_i^2 \\ \sum_{i=1}^{n} x_i & \sum_{i=1}^{n} x_i^2 & \sum_{i=1}^{n} x_i^3 \\ \sum_{i=1}^{n} x_i^2 & \sum_{i=1}^{n} x_i^3 & \sum_{i=1}^{n} x_i^4 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} \sum_{i=1}^{n} y_i \\ \sum_{i=1}^{n} x_i y_i \\ \sum_{i=1}^{n} x_i^2 y \end{bmatrix} \qquad (28)$$

The results using Second Order Polynomial show that power demand by Bayelsa State in 2025 is 272.25 MW. The method gives an error of 0.66, indicating the deviation of forecast values from the real values using the method and the least error amongst the forecast methods. It was noticed from daily load demand log sheets that peak loads occur between 6am-9am and 7pm-9pm. This is because it is a newly created state where most of the work forces are civil servants. In the morning, they prepare for work. At close of work by 4pm, they get home between 4.30pm-6pm and carry out their domestic functions between 6pm-9pm. Table 4 shows the Electricity Power Demand forecast values for Bayelsa State using Second Order polynomial method while Table 5 shows the error values for this method.

Although the Second Order Polynomial gives the highest load demand for Bayelsa State by 2025, it gives the least error recorded so far from all the models employed in the forecast because a second-order polynomial often provides a good approximation to the shape of $f(x)$ near and optimum. Fig. 4 shows the predicted and actual values of Electricity demand for Bayelsa State using Second-Order polynomial method.

8. EXPONENTIAL FUNCTION

Bayelsa State is a fast developing state and it is good to put industrial development or expansion of existing industries into account in this research. To account for these anomalies, the exponential function will be employed to obtain a best fit for the period this research was carried out. Exponential functions are expressed as;

$$Y = AB^X \qquad (29)$$

To solve the exponential function, equation 29 can be linearized by multiplying through by the log function, hence we have;

$$\log Y = \log(AB)^X$$

$$\log Y = \log A + X \log B \qquad (30)$$

Let $\quad Y^{'} = \log Y, A^{'} = \log A, B^{'} = \log B \quad$ and $X^{'} = X$

Substituting in equation 30 we get;

$$Y^{'} = A^{'} + B^{'} X^{'} \qquad (31)$$

Table 4. Forecast values for second-order polynomial method

Year X	$x = X - 2005$	y_x (MW)	x^2	x^3	x^4	xy	$x^2 y$
2006	1	37.32	1	1	1	37.32	37.32
2007	2	39.36	4	8	16	78.72	157.44
2008	3	40.32	9	27	81	120.96	362.88
2009	4	42.62	16	64	256	170.48	681.92
2010	5	48.51	25	125	625	242.55	1212.75
	$\Sigma = 15$	$\Sigma = $ 208.13	$\Sigma = $ 55.0	$\Sigma = $ 225.0	$\Sigma = $ 979.0	$\Sigma = $ 650.0	$\Sigma = $ 2452.31

Table 5. Error values for 2nd order polynomial method

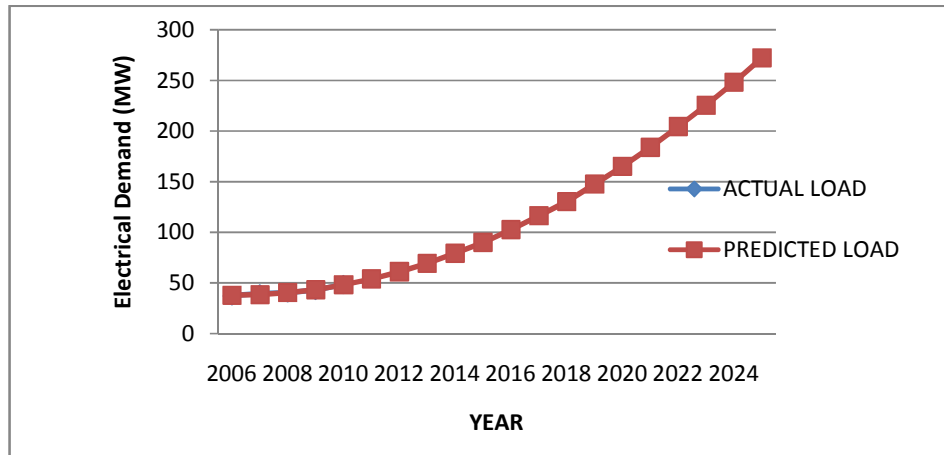| x	y_x (MW)	y_P (MW)	Error (e)	e^2
1	37.32	37.79	-0.47	0.22
2	39.36	38.43	0.93	0.86
3	40.32	40.37	-0.05	0.0025
4	42.62	43.21	-0.99	0.98
5	48.51	48.15	0.36	0.13
				$S_r = 2.19$

Fig. 4. Second-order polynomial method results

Equation (31) is the linearized exponential function. Obtaining a matrix of the linearized exponential function, we have;

$$\begin{bmatrix} n & \sum X_i^{'} \\ \sum X_i^{'} & \sum X_i^{'2} \end{bmatrix} \begin{bmatrix} A^{'} \\ B^{'} \end{bmatrix} = \begin{bmatrix} \sum Y_i^{'} \\ \sum Y_i^{'} X_i^{'} \end{bmatrix} \quad (32)$$

And applying Crammer's rule we get;

$$A^{'} = \frac{\sum Y_i^{'} \sum X_i^{'2} - \left(\sum X_i^{'} \sum Y_i^{'} X_i^{'} \right)}{n \sum X_i^{'2} - \left(\sum X_i^{'} \right)^2} \quad (33)$$

$$B^{'} = \frac{n \sum Y_i^{'} X_i^{'} - \sum X_i^{'} \sum Y_i^{'}}{n \sum X_i^{'2} - \left(\sum X_i^{'} \right)^2} \quad (34)$$

Where $A^{'} = \log A \Rightarrow A = 10^{A^{'}}$

$$B^{'} = \log B \Rightarrow B = 10^{B^{'}}$$

The results using the Exponential Function method show that power demand by Bayelsa State in 2025 is 114.44 MW. The method gives an error of 1.19 indicating the deviation of forecast values from the real values using the above method. Table 6 shows the Electrical Power Demand forecast values for Bayelsa State using Exponential function method while Table 7 shows the error values for this method.

The small error obtained using exponential function is attributed to some reasons. Exponential smoothing is easier to implement and more efficient to compute, as it does not require maintaining a history of previous input data values. Furthermore, there are no sudden effects in the output as occurs with some forecasting methods. With exponential smoothing, the effect of the unusual data fades uniformly as it has a big impact when it first appears. Fig. 5 shows the actual and predicted values of Electrical power demand for Bayelsa State using Exponential function method.

Table 6. Forecast values for exponential function method

X	$x = X - 2005$	y_x (MW)	$y = \ln Y$	$xy = X \ln Y$	x^2
2006	1	37.32	3.62	3.62	1
2007	2	39.36	3.67	7.34	4
2008	3	40.32	3.70	11.10	9
2009	4	42.62	3.75	15.0	16
2010	5	48.51	3.88	19.40	25
	$\Sigma = 15$		$\Sigma = 18.62$	$\Sigma = 56.46$	$\Sigma = 55.0$

Table 7. Error values for exponential function method

x	y_x (MW)	y_P (MW)	Error (e)	e^2
1	37.32	36.60	0.72	0.52
2	39.36	38.86	0.50	0.25
3	40.32	41.27	-0.95	0.90
4	42.62	43.82	-1.25	1.44
5	48.51	46.53	1.98	3.92
				$S_r = 7.03$
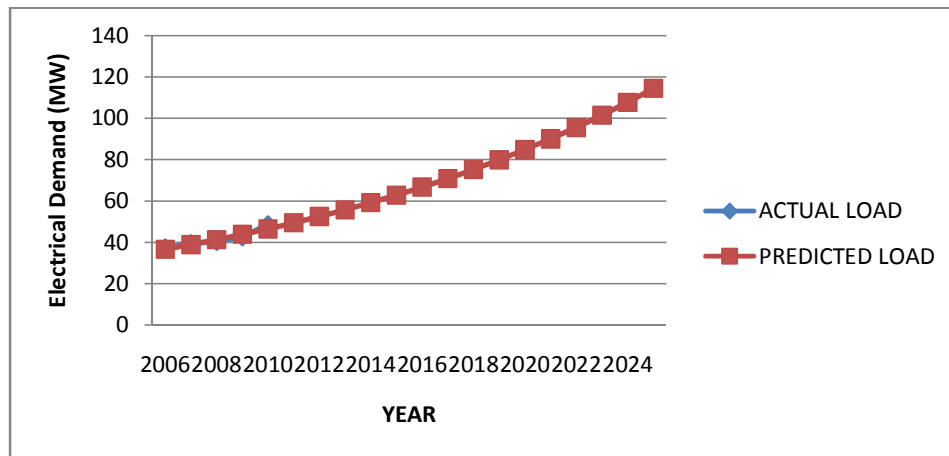
Fig. 5. Exponential function result

9. POWER FUNCTION

Equation of the form $y = ax^n$ is called power function equation where a and n are constants. The equation can transform into a straight-line form by taking logarithm of both sides. The equation will then become;

$$\log y = n \log x + \log a \qquad (35)$$

Comparing with the standard straight-line equation, $y = mx + c$, we see that a plot of $\log y$ against $\log x$ is a straight line with $m = n$ and $c = \log a$,

$$\therefore c = \text{antilog of } a$$

The results using the Power Function shows that power demand by Bayelsa State in 2025 is 78.93 MW. The method gives an error of 2.20 indicating the deviation of forecast values from the real values using power function. Table 8 shows the Electrical Power Demand forecast values for

Bayelsa State using Power function method while Table 9 shows the error values for this method.

In considering the power function model, the data may not actually be linear but the use of power function transform the equations into a linear form through mathematical manipulations before applying the simple linear regression to fit the equations to the data, hence the least error is obtained.

Fig. 6 shows the predicted and actual values of Electricity Demand for Bayelsa State using Power function model.

10. FORECAST BY TIME SERIES

Time Series analysis consist of a description (generally mathematical) of the component movements present; to understand the movement involved in such description, the technique of analyzing time series assumes that the time series variable Y is a product of the variables T, C, S and I that produces the trend, cyclic, seasonal and irregular movements, respectively. Mathematically,

Table 8. Forecast values for power function method

X	$x = X - 2005$	y_x **(MW)**	$\log x$	$\log y$
2006	1	37.32	0.0	1.572
2007	2	39.36	0.301	1.595
2008	3	40.32	0.477	1.606
2009	4	42.62	0.602	1.630
2010	5	48.51	0.699	1.686

Table 9. Error values for power function method

x	y_x (MW)	y_P (MW)	Error (e)	e^2
1	37.32	37.32	0	0
2	39.36	44.38	-5.02	25.20
3	40.32	49.12	-8.90	77.44
4	42.62	52.78	-10.16	103.23
5	48.51	55.81	-7.30	53.29
				$S_r = 25916$

$$Y = T \times C \times S \times I = TCSI \qquad (36)$$

10.1 Error Estimation

The results using Time Series shows that power demand by Bayelsa State in 2025 is 85.19MW. The method gives an error of 1.27, indicating the deviation of forecast values from the real values using Time Series. Table 10 shows the Electrical Power Demand forecast values for Bayelsa State using Time series method while Table 11 shows the error values for this method.

In using the Time Series model, there is a positive relationship between load demand and year; as the year increases, the load demand increases. Although Time Series gives an error more than some of the models, it gives a more reliable forecast because it considers general mathematical description of movement present in the series. The increased error may be due to the decomposition of series into its basic components (T+C+S+I) which are not presented in the other

models. The method gives a better fit because time is a physical concept, hence parameters and other characters of mathematical models can be real world interpretation.

Fig. 7 shows the actual and predicted values of Electricity power demand for Bayelsa State using Time series method.

11. CONCLUSION

In summary, there exist a very strong positive relationship between Power Demand and Year; that is, as the years increases, demand in electricity increases. This positive relationship between the two variables (Power Demand and Time) is shown in all the methods adopted in the analysis. This positive relationship is attributed to the fast rate of development of Bayelsa State; Bayelsa State is a "virgin" state and it is a good site for investors, hence the sudden increase in population and power demand.

Table 10. Time series values

Year X	$x = X - 2005$	Trend value, y_t
2006	1	$33.95 + 2.56(1) = 36.51$
2007	2	$33.95 + 2.56(2) = 39.67$
2008	3	$33.95 + 2.56(3) = 41.63$
2009	4	$33.95 + 2.56(4) = 44.19$
2010	5	$33.95 + 2.56(5) = 46.75$

Table 11. Error values for time series

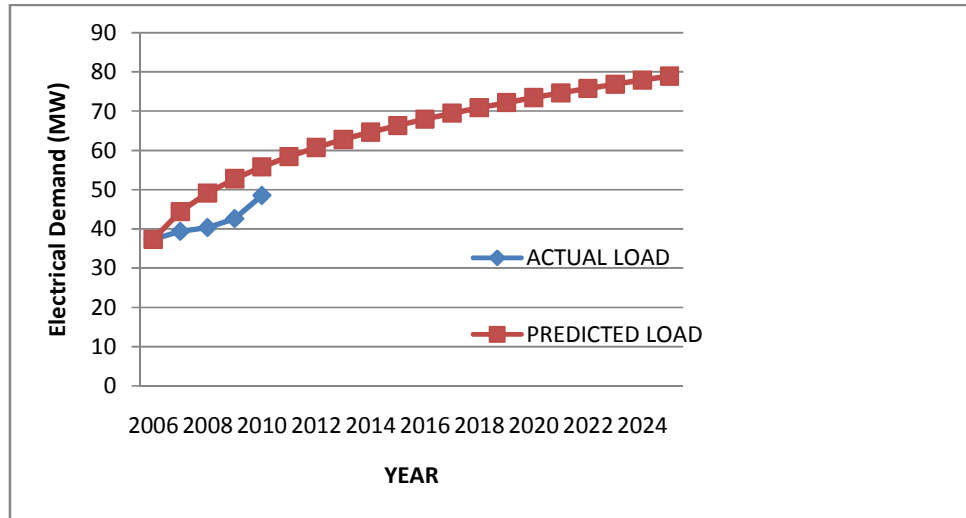| x	y_x (MW)	y_P (MW)	Error (e)	e^2
1	37.32	36.51	0.81	0.66
2	39.36	39.67	-0.31	0.10
3	40.32	41.63	-1.31	1.72
4	42.62	44.19	-1.51	2.46
5	48.51	46.75	1.76	3.10
				$S_r = 8.04$

Fig. 6. Power function results
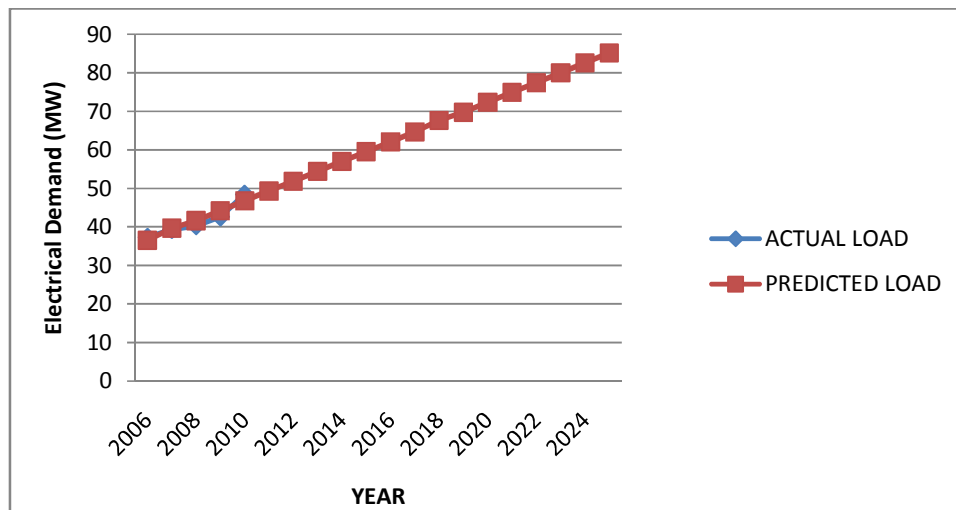
Fig. 7. Time series method results

In all the models employed in the analysis, the Second-Order Polynomial Model gives the best fit; it gives the least error of 0.66 and 272.25MW providing a good approximation to the shape of $f(x)$ function which describes the trend of the power demand distribution in Bayelsa State. Also, the daily peak load periods in Bayelsa State occur between 6am – 9am and 7pm - 9pm respectively.

12. RECOMMENDATIONS

Based on the data provided and the analysis carried out, the following recommendations are made:

- Load demand forecasting should be carried out periodically to enable power system planning and development.
- Researchers who are interested in load forecasting should adopt Second-Order Polynomial Model because it is a holistic approach and is more adequate compared to other methods used in this research work.
- Bayelsa State is fast developing; hence there is the need to step-up power generation sector (building power plants) to meet the teeming population and industrial development of the state.
- The distribution network infrastructures in Bayelsa State is of the rural setting and should be improved to reduce the power interruptions usually experienced in the state.
- Injection substations should be installed in Bayelsa State to improve the power situation and flexibility in operation of the system.

COMPETING INTERESTS

Authors declare that there are no competing interests.

REFERENCES

1. Hornby AS. Advanced Learner's Dictionary (6th ed.). New York, NY: Oxford University Press; 2000.
2. Nigerian Population Census. UNFPE Bayelsa State Population Projection; 2006. Available: www.nigeria.unfpa.org/bayelsa.
3. Leonardo RS, Lacir JS. Forecasting electricity demand: Analysis of the 2001 rationing period in Brazil; 2003. Available: http.www.citeseerx.ist.psu.edu.
4. Bhardwaj AK, Bansal RC. Electricity power demand forecasting of Kaval Cities in India. International Journal of Electrical and Power Engineering. 2010;4:85-89.
5. Bhardwaj AK, Bansal RC. Electricity power demand: A case study of Lucknow City. International Journal of Electrical and Power Engineering. 2010;2:85-89. Available:http://maxwellsci.com/print/rjaset/v3-149-152.pdf.
6. Ogunjuyigbe SOA, Adepoju GA. Application of Neural Network to Load Forecasting in Nigeria Electrical System. Paper presentation. The Pacific Journal of Science and Technology. 2007;8:2-5. Available: http://www.akamaiuniversity.us.
7. Peng PK. Electric Load Forecasting using Artificial Neural Networks and Deficit Management; 1992. Available:http://gio.uniovi.es/ant/Ponencias/Internacionales/ArtInt37.pdf.
8. Mohammed AR. Dynamic stochastic model to forecast non-stationary electricity demand. International Journal of Engineering and Advanced Technology. 2013;2(6):227-277.
9. Park DC. Price and load forecasting in the Electricity Sector. United Kingdom: Scientific Publishing; 1991.
10. Rajasekaran S. Numerical methods in science and engineering a practical approach 2nd ed., New Delhi, India: S. Chand and Company Limited. 2003;313-374.
11. Odubo GF. Load forecast in Bayelsa State by the year 2020: A case study (Master's Thesis). Rivers State University of Science and Technology, Nkpolu-Oroworukwo, PortHarcourt, Nigeria; 2007.
12. Capital City Development. Yenagoa City Master Plan; 2012. Available: www.bayelsa.gov.ng.
13. Ministry of Energy, Bayelsa State. Interim Report of Power Generation and Distribution Committee by the Bayelsa State Government. 2012;11(1):12-16.