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Assessment of Electric Load Demand and Prediction of Future Load Demand: A Case Study of Akwa Ibom State of Nigeria

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ABSTRACT
The assessment of electricity load consumption in Akwa Ibom state of Nigeria and the prediction of future electricity requirement in the state cannot be over emphasised. The data of monthly load allocation and utilization of electricity of the state in the five previous years (2006-2010) were assessed. Various engineering analysis and applications including calculations, sketches, curves and graphs were applied to justify the study. According to the annual report (IPCL., 2012), the electricity load consumption in the state in December 2011 was 130MW. This study gives the opportunity to address the risk of planning errors that could arise in the electric power upgrade planning process. The assessment however, helped in providing efficient and reliable power system management. The assessment was carried out in the three major towns in Akwa Ibom State (Uyo, Ikot Ekpene and Eket). The result obtained using the least square method and regression exponential analysis method has shown that by 2020, the electricity load requirement in Akwa Ibom state shall increase to 247.84 MW.

Key words: Electricity load assessment, load prediction, regression analysis

INTRODUCTION
There has been an aggressive demand of electricity in Akwa Ibom State due to the growing rate of industrial, economic development and increase in population (IPCL, 2007). These factors lead to frequent electric power failures, fluctuations and outages. The economic impact of these outages lead to loss of revenue of utility companies, loss of energy utilization by the customer and extra indirect costs imposed on society and the environment. (Uhunmwangho and Okedu, 2008). Society has become more dependent on reliable distribution of electricity. Simultaneously the demand for cost efficiency has increased since, it is not economically realistic to have parallel supply infrastructures (Wallnestrom, 2008). Urban electrification uses high voltage because of the long distance covered by distribution lines (Brown and Taylor, 2001). Electric distribution substations transform power from transmission voltage to lower voltages for local distribution to homes and businesses (Marcel and Bumn, 2002). Akwa Ibom State Government has sponsored a power project, called "IBOM POWER PLANT" which is situated at Ikot Abasi Town, the industrial hub of Akwa Ibom State. The power plant which has the capacity of 685 MW is to boost power supply in the state. The project is in two phases. The first phase is completed with the installation of 3 No. GE Gas turbine and 132/11KV transformer, as well as the construction of 45 km-132 KV "double circuit

power evacuation line from Ikot Abasi to Eket sub-station", offering a total capacity of 180 MW. According to the report from Nigerian oil and gas monthly journal, the second phase is expected to generate and additional 465 MW. The state would utilize only 65 MW of the power generated while the rest would be fed through a transmission line to Afam substation to the National GRID.

Objective of the study: The objective of this study is to assess the present rate of electricity consumption in Akwa Ibom State and forecast the electricity need of the state. The load allocations were obtained and matched with the demand requirement. The historical trend was analysed and used in forecasting electricity demand for a period of ten years. Forecasting is important because the future load-demand is uncertain and it helps to determine the need for new power plants or the implementation of conservation measures of electricity generation and distribution upgrade.

Justification: The frequent electrical power outages experienced in the state is traced to various defects in the electricity distribution system and inability to perform regular load analysis on the existing Injection and distribution Substations by PHCN. The overall increase in electricity demand in the residential sector combined with the increased use of electricity for industrial purposes is needed to determine how much electricity generation is available for usage.

METHODOLOGY

The forecasting methods used in this study are based on two conventional approaches viz., the extrapolation and correlation. The extrapolation approach is based on a time series analysis of the load demand curve by means of regression exponential analysis and the least square method with the suitable mathematical curves equations. These equations are fitted to the trend of the load by means of regression (exponential) analysis or least square methods, where the resulting trend line (curves) is extrapolated to the future and the projected load demand are obtained (Weedy, 1979). However, the main problem with this extrapolated approach is the choice of equation for data in the historic or previous years. In the correlation approach, the demands are correlated with selected consumer characteristics and from the expected change the trend and the future load growth established. Several models are available for forecasting such as simple curve fitting and extrapolation, Regression Model, Econometric Model, Linear optimization Model, Fourier series model, etc., but regression (exponential) trend model was also preferred to others because it can deal with large variations, missing observations and measurement errors. It conserves statistical properties when new models are generated from existing ones (Karanta and Ruusunen, 1991).

Electric load forecasting: Forecasting is a means of predicting what is going to happen in the future next month, year and decade, etc. Accurate forecasting requires high quality data, application of the appropriate forecasting technique and knowledgeable interpretation. The accuracy of such forecasts depends in large measure on the degree to which the past is a good guide to the future (Labrune and Taylor, 2001). In view of the on-going reform process, with associated unbundling of electricity supply services, tariff reforms and rising role of the private sector, a realistic assessment assumes greater importance. Utility companies must forecast demand for a long period (10-20 years). They also need to make plans to construct facilities and begin development well before the indices of forecast growth reverse or slow-down (Bansal and Pandey, 2005). The Electrical load forecast requires the determination of the future load requirement in a given power

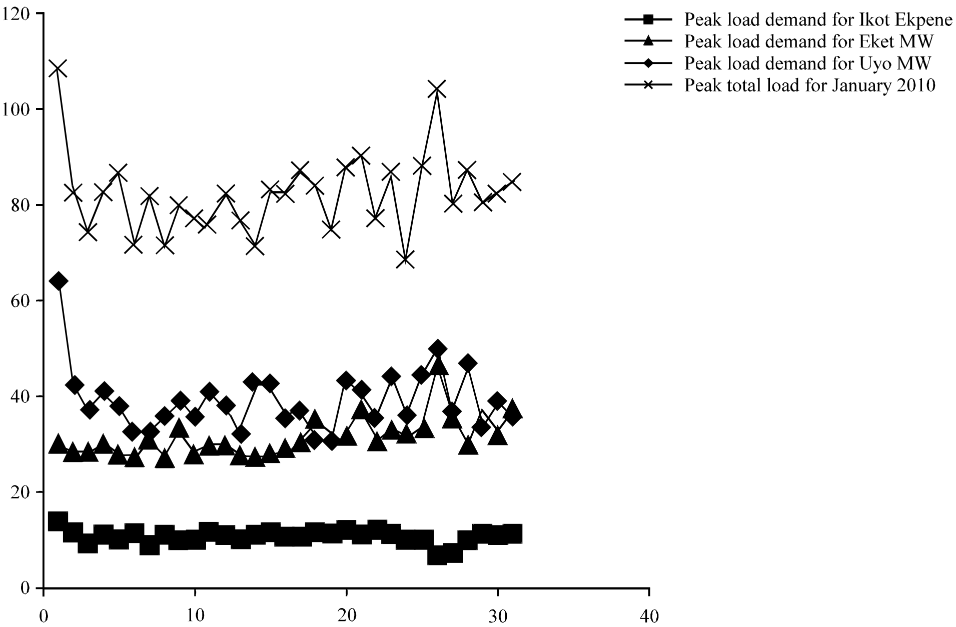

Fig. 1: Graph of daily load demand in three major towns in Akwa Ibom state in January 2010

Table 1: Peak and average load allocation and utilization (2006-2010)

Year	Allocated load (MW)	Utilized peak load (MW)	Utilized average load (MW)	Mean of loads utilised	Gaps/error
2006	103.1	107.0	102.0	104.50	-1.40
2007	104.4	107.8	103.0	105.40	-1.00
2008	105.0	108.5	105.6	107.05	-2.05
2009	106.0	115.0	109.1	112.05	-6.05
2010	114.0	118.1	116.4	117.25	-3.25

system. Load forecast also play an important role in identifying the categories to be subsidized (Cancelo and Espasa, 1991). This involves the study of the past electrical power consumption in the power system as the basis to predict the future requirement. Such studies can be grouped into short term, medium term and long term depending on the number of years in the study. Short-term forecasts which are usually from one hour to one week and medium forecasts are usually from a week to year while long-term forecasts are longer than a year (Idoniboyeobu and Odubo, 2010). There are various methods of forecasting, the predictive and the explanatory, the predictive models attempt to determine what is going to happen in the future while explanatory models attempt to explain a situation based upon empirical evidence.

Materials: The materials needed to assess the electricity load and predictions for this study is the load allocation and utilization data of the previous years from power holding company Nigeria PHCN as shown in Table 1 and 2. The curves showing the daily load demand in the towns of Akwa Ibom State in January 2010 is in Fig. 1.

The allocated load by the national control centre to Akwa Ibom State in the past five years as indicated in Table 1. It is noticed that the rate of load usage is higher than the Allocated load, the gaps which are less than zero is the indication of inadequate power allocation.

Table 2: Load allocation and utilization in three major towns in Akwa Ibom State for the month of January 2010 (MW)

	Uyo business unit-Akwa Ibom State				
		Utilization-daily peak load (MW)			
Date	Allocation (MW)	Uyo	Eket	Ikot Ekpene	Total
1	80	42.5	38.4	10.4	92.3
2	74	38.3	35.2	10.9	84.3
3	67	50.4	33.1	10.3	93.8
4	76	41.7	39.5	11.0	92.2
5	72	37.6	37.5	10.2	85.3
6	76	50.0	33.0	10.0	93.0
7	78	42.6	32.2	9.1	83.9
8	78	36.6	31.5	10.2	78.3
9	68	30.1	34.4	8.5	73.0
10	69	30.2	37.4	10.5	78.1
11	78	41.4	35.4	9.6	86.4
12	76	32.9	36.5	9.4	78.8
13	77	38.0	35.5	9.4	82.9
14	90	42.6	35.8	10.0	88.4
15	86	46.1	33.2	10.9	80.2
16	81	41.3	32.2	9.7	83.2
17	82	35.4	36.6	10.7	82.7
18	71	40.5	24.6	10.6	75.7
19	80	42.4	29.5	10.4	83.3
20	78	36.9	29.6	10.1	80.6
21	88	39.6	38.8	10.6	90.0
22	77	33.7	31.7	10.3	75.7
23	78	42.4	30.2	10.5	85.1
24	80	43.0	30.8	10.6	84.9
25	81	34.2	35.2	9.4	78.8
26	81	36.6	34.7	9.6	80.9
27	80	39.9	38.8	10.7	90.4
28	82	50.8	45.8	10.4	107.0
29	86	44.7	37.2	10.5	92.4
30	89	36.8	36.1	10.0	85.9
31	78	40.8	29.1	10.1	83.0
Monthly peak	90	50.8	45.8	10.4	107.0

In January 2010, the national control centre allocated 90 MW to Akwa Ibom State but 107 MW was utilised and as shown in Fig. 2, It is noticed that the rate of load usage is higher than the allocated load, the gaps which are less than zero is the indication of inadequate power allocation.

Calculation and analysis

Regression exponential analysis method: The curve of the data trend is non-linear in nature, therefore a non-linear model which has exponential relationship was used to achieve the estimated base load and the annual growth rate as shown in Eq. 1:

$$\text{Hence, } Y = Ae^{Bx} \quad (1)$$

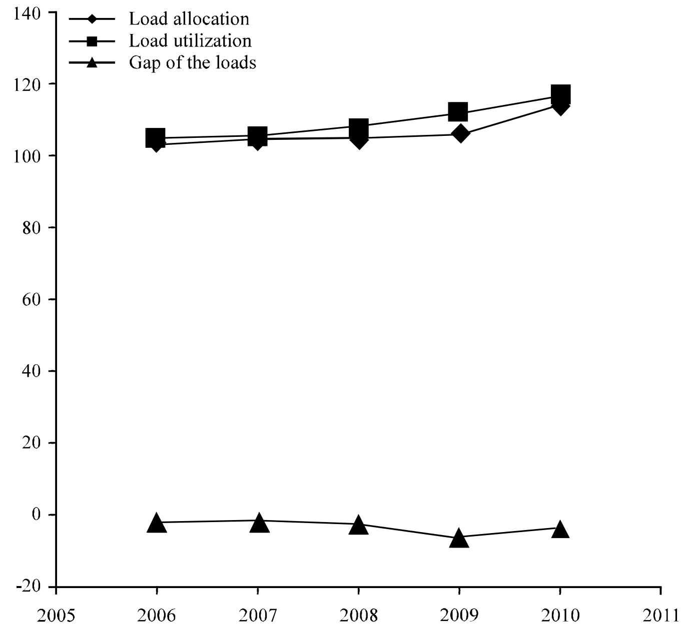

Fig. 2: Graph of loads allocated and utilized (2006-2010)

To convert Eq. 1 to a straight line form is by taking natural logarithms of both sides (Stroud and Booth, 2001). This is similar to the Eq. 2:

$$\ln Y = \ln A + Bx \quad (2)$$

Now to solve for parameters ‘a’ and ‘b’, sum up both sides of Eq. 2 which is shown in Eq. 3:

$$\Sigma \mathrm{Ln} Y = \Sigma \ln A + B\Sigma x \quad (3)$$

Multiply Eq. 3 by independent variable ‘x’ to obtain lump values as shown in Eq. 4:

$$\Sigma x \ln Y = n\ln A\Sigma x + B\Sigma x^2 \quad (4)$$

Applying crammer’s rule, we obtained Eq. 5:

$$\begin{bmatrix} n & \sum X \\ \sum X & \sum X^2 \end{bmatrix} \begin{bmatrix} \ln a \\ b \end{bmatrix} = \begin{bmatrix} \sum \ln y \\ \sum X \ln y \end{bmatrix} \quad (5)$$

Least square method: The least square method is one of the mathematical tools used in developing a curve that describe the relationship between two variables. We can establish a polynomial of any degree using the above method including the straight-line form. A relationship can be established between electricity demand and other economic variables (Gellings, 1997). Studies are being carried out to develop new techniques that would reduce the amount of data required for a given level of accuracy to be achieved in the forecasting (Gellings, 1997).

Table 3: A pair of values

X	X_1	X_2	....	X_{n-1}	X_n
Y	Y_1	Y_2	....	Y_{n-1}	y_n

A given pair of data can be represented by a polynomial that can best fit the relationship between two set of values, as given in the Table 3:

$$Y = a_0+a_1\ x+a_2x^2+a_3x^3+\ldots\ldots\ldots\ldots\ldots+a_nx_n{}^n \tag{6}$$

If the above polynomial fits the pair of data, it means that every pair of data will satisfy the equation (polynomial):

$$\left.\begin{aligned} Y_1 &= a_0+a_1\ x+a_2x^2+a_3x^3\ldots\ldots\ldots+a_nx_1^n \\ Y_2 &= a_0+a_1x_2+a_2x_2^2+a^3x_3^3+\ldots\ldots\ldots+a_nx_n^2 \\ Y_3 &= a_0+a_1x_3+a_2x_3^2+a^3x_3^3+\ldots\ldots\ldots+a_nx_n^3 \\ Y_n &= a_0+a_1x_n+a_2x_n^2+a_3x_3+\ldots\ldots\ldots\ldots+a_nx_n^n \end{aligned}\right\} \tag{7}$$

Summing all the equations above, we obtained Eq. 8:

$$\sum_{i=1}^{n} y_1 = na_0 + a_1\sum_{i=1}^{n} x_1 + a_2\sum_{i=1}^{n} x_i^2 + .. + a_n\sum_{i=1}^{n} x_i^n \tag{8}$$

From now on, we shall write the summation sign (Σ) without the i=1 to n but not that it implies multiplying Eq. 6 by $x_{i,}$ we obtain Eq. 9:

$$a_o\sum x_i + a_1\sum x_i^2 + a_2\sum x_i^3 + a_3\sum x_i^4 + \ldots\ldots\ldots + a_n\sum x_i^{n+1} = \sum y_ix_i \tag{9}$$

Multiplying (2.07) by X_i, we obtain Eq. 10:

$$a_o\sum x_1^2 + a_1\sum x_i^3\ \ a_2\sum x_i^4\ \ a_3\sum x_i^5 + \ldots\ldots\ldots + a_n\sum x_i^{n+2} = \sum y_ix_i^2 \tag{10}$$

We proceed in the same manner until the nth time and the expression will be in Eq. 11:

$$a_o\sum x_1^n + a_1\sum x_i^3\ \ a_2\sum x_i^4 + a_3\sum x_i^5 + \ldots\ldots\ldots + a_n\sum x_i^{n+n} = \sum y_ix_i^n \tag{11}$$

Altogether n+1 equations. In matrix form, this shown as in Eq. 11:

$$\begin{pmatrix} n & \sum x_i & \sum x_i^2 & \sum x_i^3\ldots\ldots\ldots & \sum x_i^n \\ \sum x_i & \sum x_i^2 & \sum x_i^3 & \sum x_i^4\ldots\ldots\ldots & \sum x_i^{n+1} \\ \sum x_i^2 & \sum x_i^3 & \sum x_i^4 & \sum x_i^5\ldots\ldots\ldots & \sum x_i^{n+2} \\ (2.8) & & & & \\ \sum x_i^3 & \sum x_i^4 & \sum x_i^5\ldots\ldots\ldots\ldots\ldots\ldots & & \sum x_i^{n+3} \\ \sum x_i^n & \sum x_i^{n+1} & \sum x_i^{n+2} & \sum x_i^{n+3} & \sum x_i^{n+n} \end{pmatrix} \begin{pmatrix} a_0 \\ a_1 \\ a_2 \\ \\ a_3 \\ a^n \end{pmatrix} \begin{pmatrix} \sum y_i \\ \sum y_ix_i \\ \sum y_ix_i^2 \\ \sum y_ix_i^3 \\ \\ \sum y_ix_i^n \end{pmatrix}$$

The least square expression obtained above can be employed in approximating the relationship between two variables using polynomial of any degree.

We can use the above expression, Eq. 8 to approximate a straight line equation by extracting 2×2 matrix from the main matrix as shown as in Eq. 12:

$$\begin{pmatrix} n & \sum x_i \\ \sum x_i & \sum x_i^2 \end{pmatrix} \begin{pmatrix} a_0 \\ = \\ a_1 \end{pmatrix} \begin{pmatrix} \sum y_i \\ \sum y_i x_i \end{pmatrix} \tag{12}$$

Note that the equation of a straight line is given by y = a_1 x+a_0. We can apply any useful method in solving the two equations in expression (11) to obtain the values of a_0 and a_1.

Applying crammer's rule, we obtained Eq. 13, 14, 15 and 16:

$$\begin{vmatrix} n & \sum x_i \\ \sum x_i & \sum x_i^2 \end{vmatrix} a_0 = \begin{vmatrix} \sum y_i & \sum x_i \\ \sum y_i x_i & \sum x_i^2 \end{vmatrix} \tag{13}$$

$$a_0 = \frac{\sum y_i \sum x_i^2 - \sum x_i (y_i x_i)}{n \sum x_i^2 - (\sum x_i)^2} \tag{14}$$

$$\begin{vmatrix} n & \sum x_i \\ \sum x_i & \sum x_i^2 \end{vmatrix} a_1 = \begin{vmatrix} n & \sum y_i \\ \sum x_i & \sum y_i x_i \end{vmatrix} \tag{15}$$

$$a_1 = \frac{n \sum y_i x_i - \sum x_1 \sum y_1}{n \sum x_i^2 - (\sum x_1)^2} \tag{16}$$

If three constants are involved a_0, a_1 and a_2 then the values of the three constants can be obtained by solving the 3×3 matrix or solving the three equations simultaneously (Idoniboyeobu and Newman, 2013).

Using regression exponential analysis method: To obtain the values of parameters 'a'and'b' in Eq. 5, use figures in Table 4.

Table 4: Peak load demand data for calculation

Year N	Year index X	Peak load Y (MW)	Lny	x Ln y	X^2	xy
2006	-2	107	4.622	-9.244	4	-203.4
2007	- 1	107.8	4.654	-4.654	1	-105
2008	0	108.5	4.686	0	0	0
2009	1	115.5	4.745	4.745	1	115
2010	2	118	4.804	9.608	4	244
	$\sum X = (0)$	$\sum Y = 0.554.8$	$\sum \text{lny} = 23.51$	$\sum \text{xlny} = 0.455$	$\sum x^2 = (10)$	$\sum \text{xy} = 50.6$

Where, $\sum X = 0$, $(\sum X^2) = 10$, $\sum XY = 50.6$, $\sum Y = 554.8$, n = 5

Substituting the value into Eq. 5:

$$= \begin{bmatrix} 5 & 0 \\ 0 & 10 \end{bmatrix} \begin{bmatrix} \ln a \\ b \end{bmatrix} = \begin{bmatrix} 23.51 \\ 0.455 \end{bmatrix}$$

Putting the values of ' a" and ' b" in Eq. 2.
We have:

- LogY = 4.702+0.0455X
- Y = exp (4.702+0.0455x)
- The value of exp4.702 = 125.17
- Therefore, a = 125.17MW
- But Y = Ae^{Bx}
- Y = {$125.17e^{0.0455x}$}, this can be expressed as in Eq. 1 Y = Ae^{Bx}

The growth rate b is obtained from the slope of Eq. 2. Which is the slope minus 1.0 but the slope is the antilog of the value (0.0455) which is 1.098.

- Then b = (1.098-1.0) X = 0.98 X 100% = 9.8%
- Estimated peak base load 'a' = 125.17 MW
- The annual growth rate' b' = 9.8%
- Therefore, Y = 125.17+9.8x. Substituting the values in Eq. 3, i.e., y = a+bx

Using the least square method: To obtain the value of b, put the values in Eq. 16:

$$b = \frac{n\sum xy + \sum x \sum y}{n\sum x^2 - (\sum x)^2}$$

$$b = \frac{(5)(50.6) + (0)(554.8)}{(5)(10) - 0^2} = \frac{253}{50}$$

$$b = 5.06$$

Put the values in Eq. 14 to obtain "a":

$$a = 110.44 \text{ MW}$$

From Eq. 3 and using least square method the estimated regression line equation is obtained thus (Table 5-7):

- Estimated base load ("a") = 110.44MW
- The annual growth rate ("b") = 5.06%
- Y = 110.44+5.06% *X
- Y = Predicted value and
- X = The year index (prediction year)

Table 5: Predicted loads Y, as per regression analysis exponential function $Y = Ae^{Bx}$

Predicted year	Predicted value: y = a+bx	New predicted value (MW)
After 1st year 2011	125.17+9.8%*1	137.43
After 2nd year 2012	125.17+9.8%*2	149.70
After 3rd year 2013	125.17+9.8%*3	161.96
After 4th year 2014	125.17+9.8%*4	174.23
After 5th year 2015	125.17+9.8%*5	186.50
After 6th year 2016	125.17+9.8%*6	198.77
After 7th year 2017	125.17+9.8%*7	211. 04
After 8th year 2018	125.17+9.8%*8	223.30
After 9th year 2019	125.17+9.8% *9	235 57
By 10th year 2020	125.17+9.8%*10	247.84

Table 6: Predicted loads Y, as per least square methods

Predicted year	Predicted value: y = a+bx	New predicted value (MW)
After 1st year 2011	110.44+5.06 *1	115.50
After 2nd year 2012	110.44+5.06*2	120.56
After 3rd year 2013	110.44+5.06*3	125.62
After 4th year 2014	110.44+5.06*4	130.68
After 5th year 2015	110.44+5.06*5	135.74
After 6th year 2016	110.44+5.06*6	140.80
After 7th year 2017	110.44+5.06*7	145.86
After 8th year 2018	110.44+5.06*8	150.92
After 9th year 2019	110.44+5.06*9	155.98
By 10th year 2020	110.44+5.06*10	161.04

Table 7: Predicted loads from 2011-2020

Year	Prediction load with exponential method (MW)	Prediction load with least square method (MW)	Gap between the predictions (MW)
2011	137.43	115.50	21.93
2012	149.70	120.56	29.14
2013	161.96	125.62	36.34
2014	174.23	130.68	43.55
2015	186.50	135.74	50.76
2016	198.77	140.80	57.97
2017	211.04	145.86	65.18
2018	223.30	150.92	72.38
2019	235.57	155.98	79.59
2020	247.84	161.04	86.80

DISCUSSION

The peak load as calculated with exponential function is 125.17 MW with annual percentage growth rate of 9.8% while using straight line i.e., least square method, load is 110.44 MW with 5.06% growth rate. Therefore, the peak load of 125.17 MW with 9.8% growth rate from regression exponential method is more realistic because it captures the elastic demand of requirement of consumers during peak and off-peak load period with appreciable growth rate. Based on the available data, it is observed that the predicted loads of this study for 2011 are closely matched the actual loads utilized in the state. For instance, the actual load for 2011 was 130 MW and this study predicted 137.43MW.

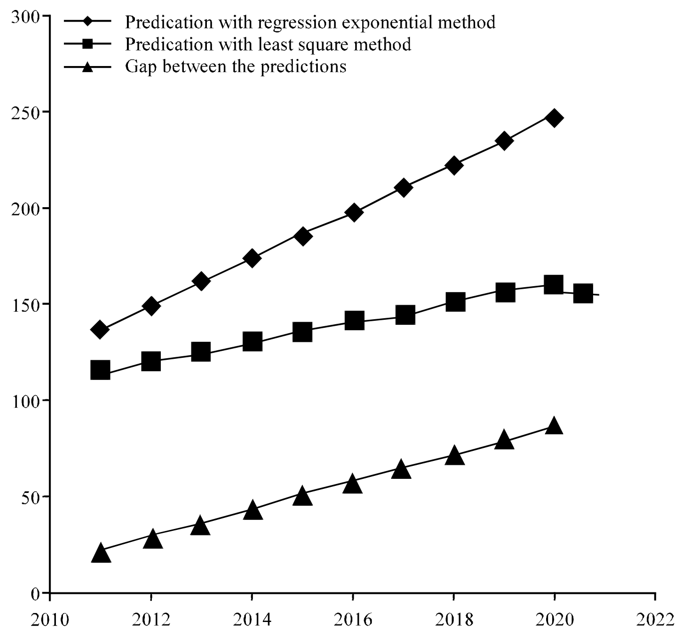

Fig. 3: Curves for predicted loads 2011-2020

Curves of future load demand (2011-2020): The curve of predicted energy demand for Akwa Ibom State is shown in Fig. 3. The curves show that the linear prediction of the exponential method has a very wide range compared with the other prediction method over a long time and it is the indication of adequate prediction.

CONCLUSION

Akwa Ibom State is strategically located given its socio-economic and industrial importance with regards to oil and gas sector. Electricity survey is a comprehensive review of electrical demand and supply pattern designed to identify areas where inefficiencies are negatively impacting the financial and service performance of the power system (Idoniboyeobu and Odubo, 2010). By the year 2020 the demand is expected to have increased to 247.84 MW of electricity in Akwa Ibom State of Nigeria.

RECOMMENDATION

The growth in electrical power demand is slow but steady. Even at that, the system capacity will be inadequate by the year 2020. It was a difficult task sourcing data from power Holding Company of Nigeria Limited (PHCN). In some cases, it was either the records which were not available or not comprehensive, however, at the end of the study, reasonable amount of data were gathered as shown from the results of the study:

- To meet the required load demand of the town an additional injection substation will be required to care for the rapid increase in the load demand (IPCL, 2007)
- The forecasting process has to take into account the effect of new technologies that may be in use in the future and based on the results of the above study

- Expansion strategy programme should be in place at the sending end (generation) to accommodate the annual growth rate, the expansion programme should consider transmission and distribution infrastructure at both sending and receiving ends
- A standard information data base is also highly recommended
- The system should be upgraded to enable it provides the necessary power requirement by the year 2020
- Further studies should be carried out to establish the level of accuracy or otherwise the two methods adopted in this project should be acceptable
- This study should be used to eliminate the risk of planning errors that could arise from many uncertainties during the power upgrade planning process

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