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LONG-TERM ELECTRIC LOAD FORECASTING FOR THE UNIVERSITY OF LAGOS USING REGRESSION ANALYSIS METHOD

By

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ABSTRACT

The University, as a centre for research into the development of a nation, requires constant supply of electricity. In order to achieve this, it becomes of great importance to evaluate the precise amount of energy required for continuous and uninterrupted power supply to the academic community. In line with this goal, this work investigates the historical load consumption of the University of Lagos community from which an electrical load forecast for the future energy requirement of this community can be proffered using the regression analysis method. It is the intent of this work to establish a mathematical model via the regression analysis method for the assessment of the historical data in order to predict a fairly reliable future energy requirement for the community, with special consideration for the next one decade i.e. long-term load forecasting. Even though this method is examined using a University Community, it can be further extended to cover the whole country, provided the historical data of the country's past electric energy consumptions are available.

Keywords: *load forecasting, predictor, electricity, long-term and planning.*

1. INTRODUCTION

Electrical load forecasting plays a very important role in the electrical power system planning, operation and management of any electricity industry. For efficient and robust economic growth and performance, there is always a need for electrical load forecast and prediction of the future electrical load demands so as to determine an estimate of the amount of load required for effective planning of the expected consumption pattern and to properly prepare for generation purposes. Load forecasting is a method of estimating the electrical load required by a certain area using previous records of load usage in that geographical area. According to Adepoju, Ogunjuyigbe and Alawode (2007), the issue in electrical load forecasting is to obtain future electrical demand values by extrapolating past load consumption and considering other factors which affect the amount of electrical load used and energy demanded at any place and at any point in time.

Due to the fact that electrical energy cannot be stored for future use with present technology, the knowledge of how electrical load behaves in the future is a very precious piece of information. Electrical utility planning begins with electrical load forecasting because of the advanced need for new utility facilities for system expansion.

Accurate models for electrical power load forecasting are essential to the operation and planning of any utility company. Hafiz *et al* (2005) once reported that load forecasting in developing countries is very difficult because of the high growth rate of load demand and the wide differences in the modes and levels of consumption from one geographical area to another. For example University of Lagos does not have the same demand as a small town in the rural area. Load forecasting helps an electric utility to make crucial and necessary decisions including decisions on purchasing and generating of electrical power, load switching, and infrastructural development. In the work of Feiberg and Genethlion, (2009), it was evident that the load forecasts are extremely important for energy suppliers, financing institutions and other participants in electrical energy generation, transmission, distribution and marketing.

Forecasts are used in the planning of buying and selling of electrical energy in interconnected systems. It is very important in the electrical industry and it has a major economic advantage as it helps the power Generating and Distributing Companies to estimate the amount of power needed to be generated and supplied to any particular geographical area since electrical energy can not be efficiently stored in large commercial quantities. It is an important tool for planning and taking operational decisions by utility companies. It is also used in the total planning of the system (Kohthari and Nagrath, 2003).

Accurate load forecast can be helpful in developing a power supply strategy and development plan especially for developing countries where the demand is dynamic in nature due to high growth rate and high rural–urban drift.

Other advantages of load forecasting include:

- Optimisation of network planning and investment
- Better and heuristic management of risk
- Reduction in cost

The issue of classification of the load forecasting was the thrust of Lidong *et al* (2006), this was presented according to both the predicted quantity (peak load, integral load, hourly load) and the prediction time.

Based on the prediction time, it can be divided into three categories. They are:

- Short-term load forecasting: This is usually from one hour to one week. It helps to estimate the load flows and to make decisions that can prevent overloading. It is used for controlling and scheduling of power for systems' input to load flow and contingency analyses.
- Mid-term load forecasting: This is usually from a week to a year; and
- Long-term load forecasting: This is longer than a year. Long-term forecasts are used to determine the capacity of generation, transmission and distribution facilities.

Ibitoye and Adenikinju (2006) showed that the factors that affect forecasting include time, weather, socio-economic conditions (working days or public festivities) and cultural conditions (special periods such as Christmas or Ramadan), historical load data, and type of area. All these factors determine the amount of power which would be required by a particular area at any particular time.

The aim of this paper is to present a fairly new electrical load forecasting model based on regression analysis method that allows the future load to be determined with degree of accuracy with the help of the past energy consumption data. The rest of the paper is outlined as follows: section 2 presents the historical record of load forecast while in section 3, the various methods of electrical load forecasting are investigated. Section 4 develops the electrical load forecasting model based on regression analysis method which is one of the most versatile methods of electrical load forecasting. The solution approach using MATLAB is advanced in section 5.To round off the work, the results obtained are displayed in section 6 and then concluding remarks are thus drawn from these results..

2.0 PREVIOUS ELECTRICAL LOAD FORECAST RECORDS

In Nigeria, serious efforts have not been made in the area of load forecasting mainly because of the erratic power supply and poor record keeping in terms of suppressed loads. This has resulted in poor planning of generation, transmission and distribution facilities. Because of the highly advantageous features of load forecasting, it has become essential to forecast load demand with respect to electricity supply in the Nigerian system so as to effectively plan and schedule for future expansion in the generation, transmission and distribution facilities.

In the University of Lagos (which is the case study in this paper), because of the special duties being carried out in this community, there is need for a 24-hour supply of electricity. Awosope (1985) evaluated the essence of load forecasting and the cost of outages to the University Community. These outages resulted in a huge amount of financial loss to the University Community. To overcome this unfortunate incidence, it becomes necessary to have an excellent load forecast (for both medium- and long-terms) in order to properly estimate the energy needs which ensures that the essential duties of research and teaching are not hampered.

According to Ajayi and Balogun (1981), the prediction of electrical load at a future time is a challenging problem because of the diverse characteristics of electrical load which range from the period of the day to day of the week as well as season under review. With respect to Oamek and Englion, (1979) and Haydari *et al* (2007), there are various useful methods for load forecasting which could be broadly divided into two main groups namely mathematical analysis (such as econometric model, time series and end-use approach) and heuristic or expert systems approach. Alfores and Nazeeruddin (2006) reported that there are several variants of relatively new heuristic methods such as El Naggour and Al Rumail (2005) who developed Genetic Algorithm based load forecasting method; Kuasisto (2005) further experimented with neural network on short-term load forecasting while Bassi and Olivare(2003) implemented same method for long-term load forecasting analysis. Srinivas and Jain (2009) implemented fuzzy logic for short-term and Jain and Satish(2008) further experimented with the support vector machine(SVM) on short-term forecasting. Oamek and Englion, (1979) and Haydari *et al* (2007), gave a brief review of the method for predicting future load demand of a community or nation using the latest computing technology.

3.0 ENERGY CONSUMPTION PATTERN IN NIGERIA

Nigeria is a country with a population of about 140 million people with an installed electrical power generating capacity of about 6,000MW of which a maximum of 4,500MW has been running at the best of times. The latter amount of available power is commensurable to the electrical power demand of the whole populace which has been put at a value (for short-term demand) of 8,000MW and a long-term demand of 40,000MW for the first decade of this millennium. Thus in order to satisfy the energy needs of the entire nation, Nigeria needs an installed capacity of at least 40,000MW. This is a herculean task with regards to the currently available capacity. Meanwhile this wide gap between the available capacity and expected capacity could be associated with a lot of factors ranging from inadequate and poor infrastructural planning to expansion of the currently available generating units and stations. Due to all these factors, the electricity supply in Nigeria is being endangered.

The University of Lagos is a microcosm Nigeria with a mixed community which consists of educational, residential and commercial facilities that require constant supply of electricity. It should be put on record that the Nigeria's electricity utility industry (the Power Holding Company of Nigeria) has a transmission station within the Akoka Campus of the university. According to Awosope (1985), the initial purpose of this station is to

provide uninterrupted electricity to the University community. This has not been the case since the generated electricity is not adequate. Thus due to the dependence on the Power Holding Company of Nigeria, and its characteristic erratic power supply then it is imperative for the University to properly plan its power demand and consumption pattern.
Adequate plan for uninterrupted power supply is made through the provision of alternative means of supplying electricity to the community whenever the national utility company is unasble to provide the service. To ensure that this goal is achieved then a nearly precise and unambiguous electrical load forecasting is suggested to provide a close estimate of the amount of electricity required for the whole University Community.

4.0 ANALYSIS OF THE FUTURE LOAD USING THE REGRESSION ANALYSIS METHOD

The regression analysis method is the statistical technique that constructs a model used to determine the value of a dependent variable from available knowledge of the independent or explanatory variable.
The method has found ample usage in several areas such as *ex-post* evaluation, to determine the net impact of the programmes. The process of implementation is shown in figure 1 which is later explain below.

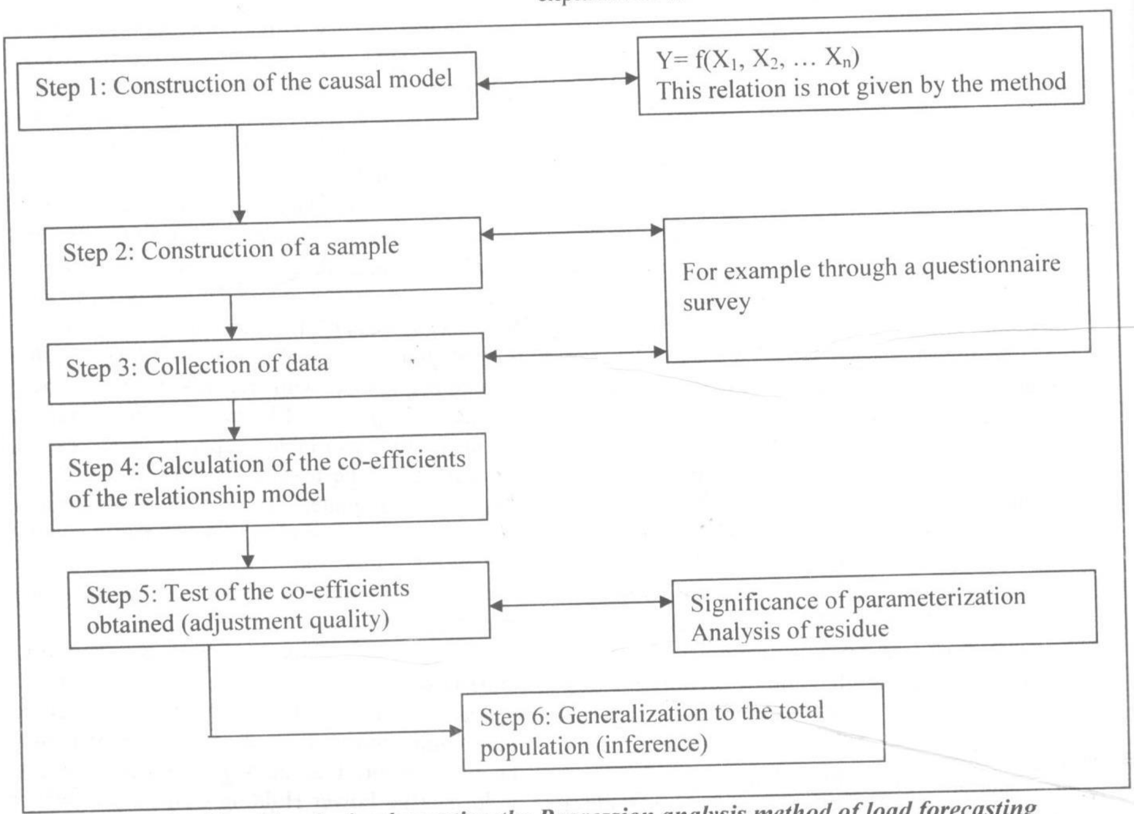

Figure 1: Algorithm for implementing the Regression analysis method of load forecasting

Step 1: Construction of the causal model

This is a crucial step due to the fact that it determines the nature of the presumed model in such a way that a particular variable could evolve as a linear, logarithmic, exponential or any other function. All the explanatory models are constructed on the basis of the model shown in equation (1)

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k + \varepsilon \quad (1)$$

where

Y : the change that the programme is mainly supposed to produce from X_{1-k}

X_{1-k} : set of independent variables likely to explain the change.

β_{0-k} : set of constants, and

ε : the error term

Step 2: Construction of a sample

To apply multiple regressions, a large sample size is usually required (ideally between 2,000 to 15,000 individuals). However for time series data, much less sample size is required.

Step 3: Data collection

Reliable data must be collected, either from a monitoring system, from a questionnaire survey or from a combination of both.

Step 4: Calculation of coefficients

Coefficients can be calculated relatively easily, using statistical software that is both affordable and accessible to personal computer (PC) users.

Step 5: Test of the model

The model aims to explain as much of the variability of the observed changes as possible. To check how useful a linear regression equation is, tests can be performed on coefficient of determination, r^2.

Step 6: Generalization to the total population

The purpose of this phase is to generalize the coefficients of the model to the population as a whole. It is therefore used to produce an estimation of the effects.

This technique can show a high degree of dependence of variables with respect to the proportion of variance between such variables. On the other hand, it is also possible to evaluate this proportion in relationship to the various independent variables in the system equations(Alfores and Nazeeruddin,2006; El Naggour and Al Rumail, 2005; Kuasisto, 2005; Haydari *et al*, 2007). The relationship between the variables is usually expressed in form of a set of equations from which a generalized equation could be propounded. So also, it can be illustrated graphically.

There are two types of the regression analysis methods namely, simple and multiple regression methods. A simple regression analysis method can show that the relationship between an independent variable X and a dependent variable Y is linear, using the simple linear regression equation

$$Y = a + bX \quad (2)$$

(where a and b are constants).

In the case of the multiple regression analysis method, it involves the development of an equation that can predict one variable with the help of two or more relevant independent variables in such a manner that the equation can be set up as:

$$Y = a + bX_1 + cX_2 + dX_3 \quad (3)$$

4.0 SOLUTION APPROACH

To solve the problem of the long-term load forecasting in the University Community, the following steps were taken:

- Past records of data of the energy consumption of the community was acquired
- The data was then presented graphically to obtain the desired trend.

- The trend obtained was then converted to a suitable mathematical model.

- Thus a mathematical model was developed to determine the expected future load forecast.

From the foregoing therefore, the graphs of the measured data shown in table 1 are as revealed in figure 2. Each of the graphs is plotted for each month from which equation (4) for each of the trends is obtained which expresses the equation of consumption trend line for each of the months. According to equation (2), the solution for the load forecast is better accomplished from the perspective that there are no consistent minimum (MIN), average (MEAN) and maximum (MAX) consumption values in an examined period of time over a set of months or years. This is due to the fact that each year has its unique high (or low) value of energy requirement considering the respective months which depicts the seasonal variations during corresponding months of each successive year. Thus, based on the inherent discrepancies in the individual trend characteristics of the expected energy consumption curves, then it becomes easy to employ the least squares method for fine-tuning the observed quantitative data in table 1. The method employed results in the modelling of a non-periodic, non-linear parametric time series (Lidong *et al*, 2006) set of polynomial relationships between the antecedent (*precursor*) and consequent (*logical conclusion*) functions respectively that lead to the intricate number of equations.

JANUARY: $p(x) = -545.8x^3 + 3E{+}06x^2 - 7E{+}09x + 4E{+}12$ (4a)

FEBRUARY: $p(x) = 7436.4x^3 - 4E{+}07x^2 + 9E{+}10x - 6E{+}13$ (4b)

MARCH: $p(x) = 6753.2x^3 - 4E{+}07x^2 + 8E{+}10x - 5E{+}13$ (4c)

APRIL: $p(x) = 4631.9x^3 - 3E{+}07x^2 + 6E{+}10x - 4E{+}13$ (4d)

MAY: $p(x) = 8653.4x^3 - 5E{+}07x^2 + 1E{+}11x - 7E{+}13$ (4e)

JUNE: $p(x) = 6849x^3 - 4E{+}07x^2 + 8E{+}10x - 5E{+}13$ (4f)

JULY: $p(x) = 5465.3x^3 - 3E{+}07x^2 + 7E{+}10x - 4E{+}13$ (4g)

AUGUST: $p(x) = 8668.4x^3 - 5E{+}07x^2 + 1E{+}11x - 7E{+}13$ (4h)

SEPTEMBER: $p(x)=9986.3x^3-6E{+}07x^2+1E{+}11x-8E{+}13$ (4i)

OCTOBER: $p(x)=12819x^3 - 8E{+}07x^2 + 2E{+}11x - 1E{+}14$ (4j)

NOVEMBER: $p(x) =15190x^3-9E{+}07x^2+2E{+}11x - 1E{+}14$ (4k)

DECEMBER: $p(x)=10800x^3 6E{+}07x^2+1E{+}11x-9E{+}13$ (4l)

The monthly relationship (depicted in eqns (4a) to (4l)) leads to the generation of the family of curves shown in figures 2 and 3.

Nevertheless, in relation to activity levels, the electrical load p is a single-value time dependent seasonal entity with respect to specific months of each successive year (Alfores *et al*, 2006). Thus, irrespective of the activity-related energy utilization predictor attributes, the required least-squares line is derived from the relation

$$p(x)=\bar{p}+\left(\frac{\sum XP}{\sum X^2}\right)x = \frac{\sum Y}{n}+\left(\frac{\sum XP}{\sum X^2}\right)x \qquad (5)$$

which results in;

$$p(x) = 1358620 + 112972x \qquad (6)$$

The above development which utilizes the prediction approach, where x is measured in halfyears then this implies that the values of load consumption with respect to time (i.e. energy consumption), $p(x)$, increases by 112972 kWh every half-year, or by 112972/6 = 18828.67 kWh every month as can be predicted from the available data as follows:

Using eqn (6), at the beginning of the year 2004 (this is taken as the base year); $x = 0$ (i.e. on Jan. 1, 2004) this means that $p(x)$ = 1358620 kWh. A half-way down to the month later, (i.e. on Jan. 15, 2004) the value of load consumed can be determined as $p(x)$ = 1358620 + ½(18828.67) = 1368034.34 kWh. By successively adding 18828.67 kWh to 1368034.34 kWh, the trend values for February 2004, March 2004, etc respectively become 1368034.34 + 1(18828.67) = 1386863.01 kWh, 1368034.34 + 2(18828.67) = 1405691.68 kWh, etc. Similarly, by successively subtracting 18828.67 kWh from 1368034.34 kWh, the trend values for December 2003, November 2003, etc., respectively becomes 1368034.34 – 1(18828.67) = 1349205.67 kWh, 1368034.34 – 2(18828.67) = 1330377 kWh, etc.

As such, without recourse to any form of mathematical ambiguity as shown in eq. 5, and especially to streamline the number of input parameters, the simplified load predictor model for subsequent period $k_1, k_2, k_3\ldots, k_n$ becomes

$$p(k) = 1368034.34 + 18828.67k \qquad (7)$$

where

$$k = 12(y_k - 1) + x \quad (6)$$

with

$$k = \begin{cases} + & \text{when } y_p > y_o \ (\text{or } y_k > 0) \\ - & \text{when } y_p < y_o \ (\text{or } y_k < 0) \end{cases}$$

$y_k = y_p - y_o$, if $y_k = 1$,
then $(y_k - 1) \rightarrow 1$ is assumed where appropriate.

x is the assigned numerical value of the desired forecast month (e.g., *January = 1*, *February = 2*, ..., *November = 11*, and *December = 12*).
y_o is the assumed base year (that is, year 2004), and y_p is the desired year of a particular forecast (e.g., year 2011).
From this simplified linear relation, the forecast of any long-term trend can be suitably approximated

6.0 RESULTS AND DISCUSSION OF RESULTS

The results are shown in Tables 2, 3 and 4. Using the model developed above, the monthly electrical load is predicted as shown in table 2. Table 3 shows the error in each predicted value from March 1999 to May 2009. The error values strongly support the proposition that the regression analysis method is quite suitable for the long-term load forecasting in which case other factors (such as weather, etc) that usually inhibit accuracy in load forecasting may not necessarily be incorporated into the functional equations. This clearly enunciates the future load demand of the University Community under the period of study as shown in table 4.
It should also be noted that the large deviations in load are due to factors such as inconsistent sessions (due to strikes, student riots etc). So the high and the low periods are not uniform across the years. This has resulted in some inconsistencies in the results.
By and large, in consonance with Nigeria's aspiration and plan for full industrialization and development by the year 2020, thus the University as the hub for active research and development towards the achievement of this vision must have a very good understanding of its load requirement in order to assist in realizing the Government's desires hence the University of Lagos as one of the leading research and training centres in Nigeria would need a progressively increasing power demand as forecasted in this paper up to year 2020.

7.0 CONCLUSIONS

From the above discussion, it can be concluded that: it is possible to apply this method to long-term load forecast and the process does not involve a whole lot of tedious mathematical calculations and hence can be easily understood by the policy makers as well as system operators and planners.

8.0 RECOMMENDATION

Since electricity is very vital to economic and technological growth of any nation, thus this model can be implemented to evaluate and obtain the exact amount of electricity needed by Nigeria for the actualization of the Nigeria's Vision 20:2020.

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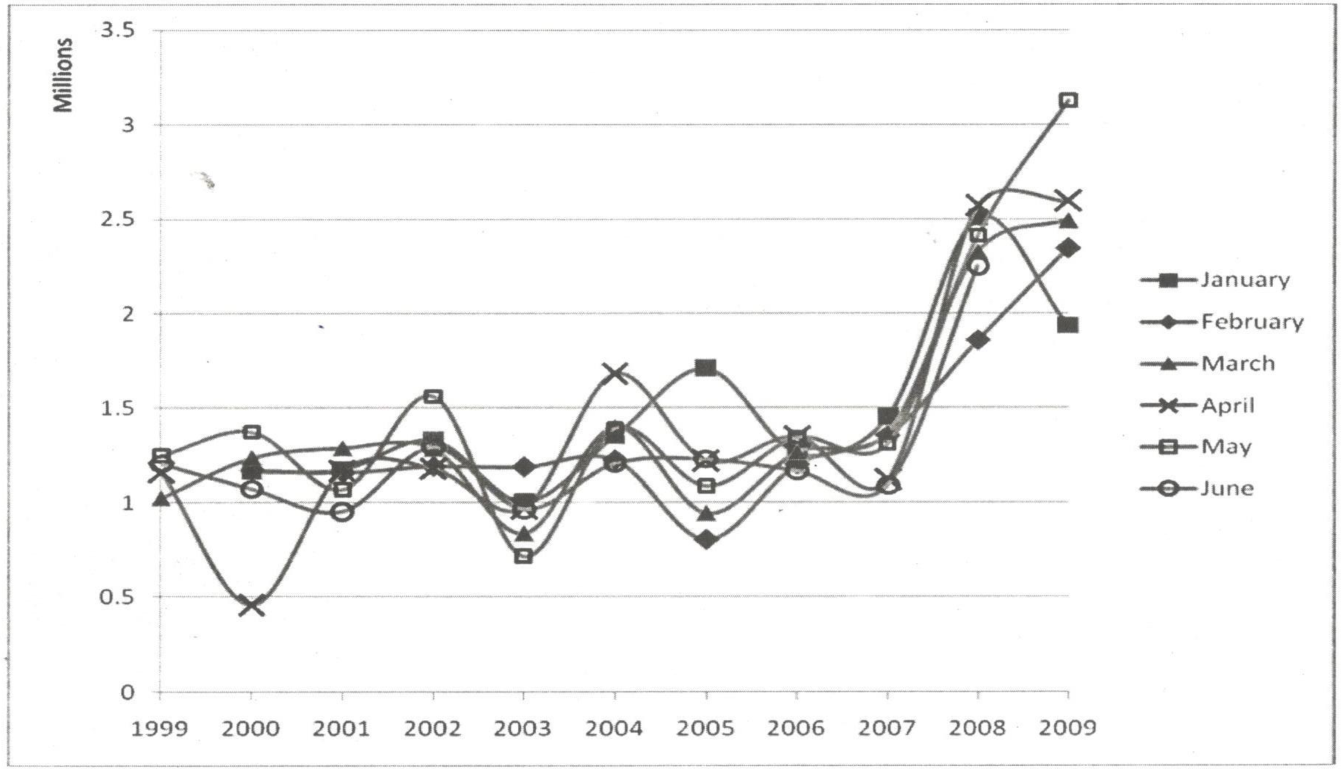

Figure 2: Graph showing the monthly electric load consumption of the acquired data for January

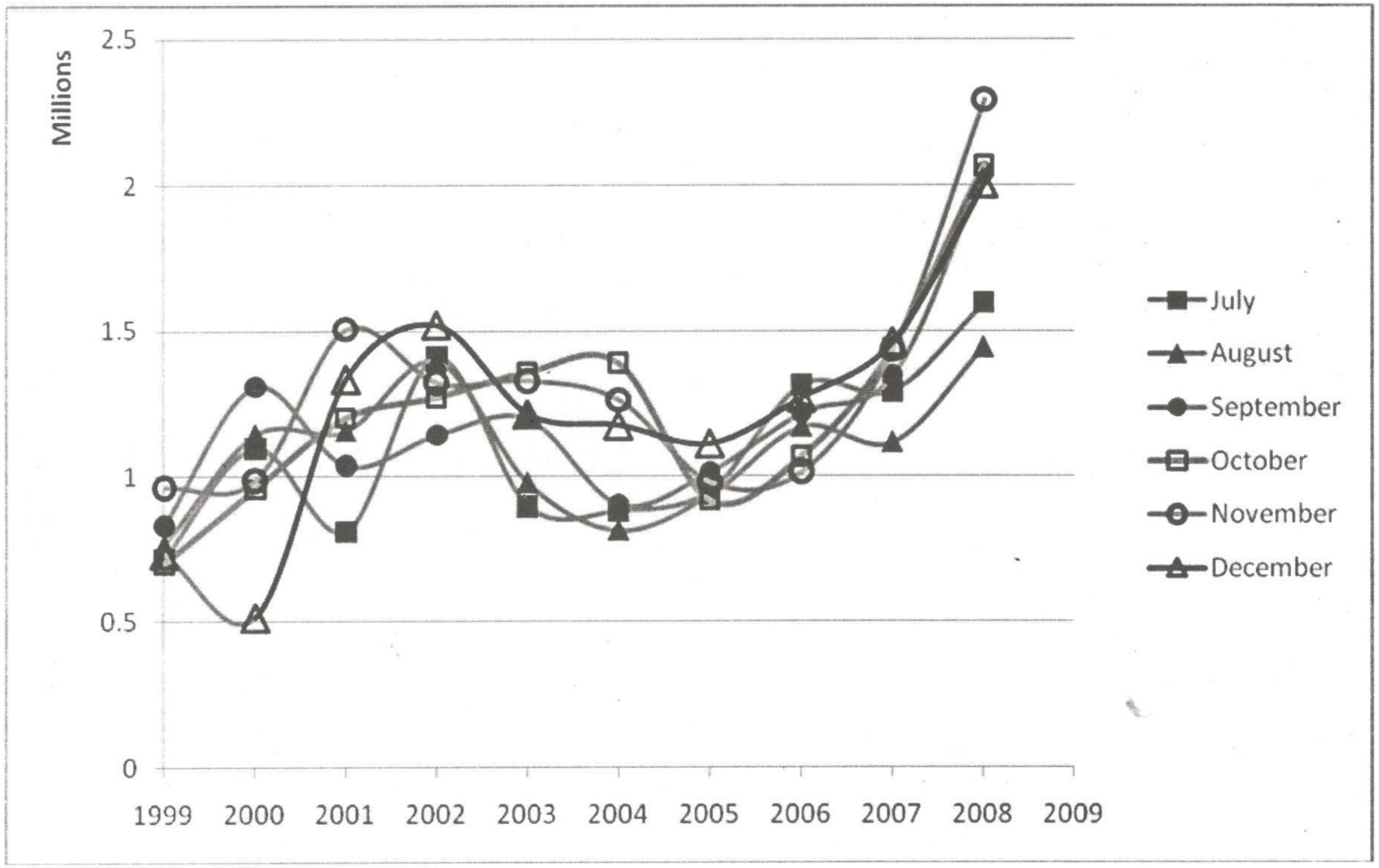

Figure 2b: Graph showing the monthly electric load consumption of the acquired data for February

Table 1: Measured monthly electric energy consumption in kWh of Utilities in University of Lagos from March 1999 – May 2009

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
JAN		1163700	1175300	1329700	1002600	1355000	1709900	1260000	1454300	2504720	1935160
FEB		1172300	1158400	1191300	1188400	1226400	804200	1200900	1356300	1859540	2343600
MAR	1022600	1236000	1288200	1284767	836300	1401700	941900	1265000	1369000	2325600	2492750
APR	1162500	458200	1168200	1179100	967800	1681700	1220000	1349900	1118500	2570280	2591950
MAY	1248100	1373800	1066700	1561800	714900	1393400	1085000	1344000	1311400	2410860	3125608
JUN	1203900	1069800	951400	1291900	962300	1204800	1226800	1165000	1088400	2248830	
JUL	717900	1095210	809100	1406700	895800	879800	948800	1312600	1291700	1594490	
AUG	765200	1143700	1156200	1395900	977500	814700	935500	1170000	1116300	1443730	
SEP	833000	1306700	1035900	1141100	1197700	902800	1014800	1217100	1345000	2043320	
OCT	699200	955100	1200000	1270500	1355300	1387100	916000	1066500	1436900	2067260	
NOV	962400	986000	1504400	1321000	1327700	1261200	977300	1013500	1433600	2291660	
DEC	732400	515000	1333300	1519100	1213100	1173700	1110500	1268500	1460800	2004650	
MEAN	934720	1034573	1153925	1324406	1053283	1223525	1074225	1219417	1315183	2113745	2497814