



Development of Software Algorithm for Energy Modeling and Forecasting

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ABSTRACT

The problem of repetitive calculations involved in the comparative analysis of forecasted energy loads to determine the most applicable model out of a variety has been reduced by the development of a forecasting software algorithm done in this work. Three models and two test tools were catered for by the developed software at this preliminary stage. They are the linear, compound growth and cubic models while the test tools are the rank of correlation coefficient (ROCC) and the mean absolute percentage error (MAPE). The numerical modelling and forecasting procedures were presented and an algorithm flow chart was subsequently developed for the software. The programming language selected for the design of the software is MATLAB because of its versatility in mathematical applications. On the completion of the software, it was applied to an existing energy consumption case study available in literature to ascertain its reliability. The results obtained were in the range of the estimations found in literature.

Keywords: Modeling, Forecasting, Linear, Compound-growth, Cubic, Software

1.0 INTRODUCTION

In the recent times, the application of interactive software algorithms have made tremendous impact in the field of technology and engineering, various computer-aided methods are now used in virtually all its aspects of human endeavour. This work is on the development of a software algorithm to model and forecast energy loads with a possible choice of three different forecasting models. The developed software does not only remove the tedium associated with energy modeling and forecasting procedures but also speeds it up dramatically thereby making the process of analyzing hundreds of energy load values easier and faster. Energy is considered as one of the most important resources of any community or country. The energy available in a country and the extent its utilisation affects the rate of industrial growth in that country (Saab, S., et al, 2000).

Different researchers are continually propounding new methods for energy modelling and forecasting (Fadare, 2010; Enege *et al.*, 2012; Antonio *et al.*, 2004; Breipohl and Douglas, 1998,). Different models must be applied to meet different class of load forecasting depending on the set objectives (Zaid et al, 2003). Models that have been used over the years include; regression methods (linear and quadratic), Artificial Neural Network (ANN), Static state estimation method, the Gaussian Process models, time series, expert systems, fuzzy logic, the reference forecast, forecast by the use of national economic and demographic variables and many others (Douglas *et al.*, 2004). In this work, the models used are Linear models, compound-growth model, and the cubic model approach. The Pearson's rank of correlation coefficient and mean-absolute-percentage-error are used for testing the model that suits the forecast.

FORECASTING MODELS AND NUMERICAL COMPUTATIONS

2.1 Description of Forecasting Models and Test Tools

The development of the software algorithm done in this work was based on three forecasting models, namely, the Linear, Cubic and compound growth models. The Linear Model has the form of



representation of two specific variables, the independent and dependent variables. Y is load at a given year X, it states that, $Y = a + bX$ where a and b can be obtained from equation (1)

$$\sum Y = na + b \sum X \text{ and } \sum XY = a \sum X + b \sum X^2 \dots\dots\dots (1)$$

The Excel algorithm has an expression common to normal straight line equation which is $y = mx + c$, where n is the number of years and the constants m and c can be obtained from equation (2) and (3);

$$m = \frac{n \sum xiyi - (\sum xi)(\sum yi)}{n \sum xi^2 - (\sum xi)^2} \dots\dots\dots (2)$$

$$c = \frac{(\sum yi)(\sum xi^2) - (\sum xi)(\sum xiyi)}{n \sum xi^2 i - (\sum xi)^2} \dots\dots\dots (3)$$

The Compound-Growth Model is expressed in form of equation (4) and the constants c and d can be found when solved simultaneously from equation (5).

$$Y = \text{antilog}(c + dx) \dots\dots\dots (4)$$

$$\sum \log Y = nc + d \sum X \text{ and } \sum X(\log)Y = c \sum X + d \sum X^2 \dots\dots\dots (5)$$

The Cubic regression model has the form given in equation (6). It relates peak load (y) and the years (X). The values of a_0 , a_1 and a_2 can be solved from the equations (7);

$$y = a_0 + a_1X + a_2X^2 \dots\dots\dots (6)$$

$$\begin{aligned} a_0n + a_1 \sum x_i + a_2 \sum x_i^2 &= \sum y_i \\ a_0 \sum x_i + a_1 \sum x_i^2 + a_2 \sum x_i^3 &= \sum x_i y_i \dots\dots\dots (7) \\ a_0 \sum x_i^2 + a_1 \sum x_i^3 + a_2 \sum x_i^4 &= \sum x_i^2 y_i \end{aligned}$$

Two test tools are incorporated in the modelling software, namely, the rank of correlation coefficient (ROCC) and the mean absolute percentage error (MAPE). These tools are used in determining the appropriate model for any given situation. The rank of correlation coefficient verifies the validity and reliability of a chosen model. It foretells how reliable a model can be in its prediction. Its optimal value is unity and it is presented as equation (8)

$$r_{xy} = \frac{\sum x_i y_i - n \bar{x} \bar{y}}{n s_x s_y} = \frac{n \sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n \sum x_i^2 - (\sum x_i)^2} \sqrt{n \sum y_i^2 - (\sum y_i)^2}} \dots\dots\dots (8)$$

The Mean absolute percentage error (MAPE) is a measure of accuracy in a fitted time series value in statistical trending. It usually expresses accuracy as a percentage and is expressed as equation (9) where A_t is the actual value and F_t is the forecast value. The least value of M is the optimal unlike highest value of rank r (Fung and Tummala, 1993)

$$M = \frac{1}{n} \sum_{t=1}^n \left| \frac{A_t - F_t}{A_t} \right| \dots\dots\dots (9)$$



2.2 Description of Numerical Procedures and Need for Requisite Algorithm

There are nine basic steps involved in modeling and forecasting of energy loads using the models discussed in section 2.1. They steps are (i) *Collation and gathering of data from all local sources such as feeders in case of electricity load.* This is a various tedious stage because the local sources such as feeders may number to hundreds in some cases (ii) *Calculation of mean annual, monthly or daily load depending on the time basis for the forecast.* Once the data have been gathered in step 1, the monthly or yearly mean values for each of these local points are obtained based on the time interval being considered for the forecasting. (iii) *Determination of total mean loads for the time interval being considered.* This stage involves the addition of all the mean values at the various points to get the total load for the month or year. (iv) *Generation of table of data for the application of all models.* A comprehensive table containing all the parameters and summations required for all models is generated at this stage using the total yearly or monthly or daily mean value as the case may be. (v) *Application of models to generate load values for existing years.* The models are used to predict load for few previous years to test the reliability of the model. (vi) *Application of test tools on loads generated in step (v).* Using the forecast and actual values obtained the test tools are applied. (vii) *Comparison of MAPE and ranking (r) results for all models applied.* The models are tested for reliability using the test tools and the best model chosen from results obtained. (viii) *Choosing the most suited model based on the least MAPE and highest ranking 'r' value.* (ix) *Application of most appropriate model to predict energy trend for years ahead.* The most appropriate model based on MAPE and ranking results is herein used to forecast load for future years.

3. DEVELOPMENT OF MODELING AND FORECASTING ALGORITHM

The selected programming language for the task of developing software for energy modeling and forecasting is the MATLAB. This language is windows based and much more mathematics- oriented than other high- level languages. More so, like Visual BASIC and Visual C++ it has a GUI (Graphical User Interface) tool kit which enables the design of highly interactive interfaces.

The software developed in this work takes over the numerical process of modeling and forecasting energy loads after the computation of the total monthly or yearly loads. The software goes ahead to (i) model for existing years, (ii) test for each model, (iii) compares test results, (iv) selects the most reliable model, (v) forecasts for future years, (vi) generates various energy profiles. The flow chart of the software algorithm is presented in Figure 1 while Figures 2 and 3 are the input and result interface of the developed software.

3.3 Software Application

The developed software was used in forecasting PHCN (Power holdings corporation Nigeria) electricity consumption for residential and non residential as conducted in literature (Eneje et al. 2012). The three models namely, Linear, cubic and compound growth were used by the software and the reliability of the models were tested using the MAPE and ranking r^2 methods. The total yearly loads as obtained by Eneje et al. are presented in Table 1. Based on the figures in Table 1, equations (10), (11) and (12) are those obtained for the residential load consumption (Eneje et al.) for the linear, cubic and compound growth models respectively.

$$Y = 266.59 + 32.123X \dots\dots\dots (10)$$

$$Y = 231.0958 + 62.5438 X - 5.0702 X^2 \dots\dots\dots(11)$$

$$Y (nth) = \text{antilog} (2.4363+0.03972X) \dots\dots\dots(12)$$



The linear, cubic and compound growth models for non residential consumption as obtained by Eneje *et al.* are also presented in equations (13), (14) and (15) respectively.

$$Y = 144.62 + 11.958 (X) \dots \dots \dots (13)$$

$$Y = 129.641 + 24.8011X - 2.1405 X^2 \dots \dots \dots (14)$$

$$Y(\text{nth}) = \text{antilog} (2.13518 + 0.02947X) \dots \dots \dots (15)$$

Table 1: Input values for Software application

The Total Load For All The Feeder In Residential Area For Each Year	
X (Year)	Y (load) in MW
1 (2006)	284.79
2 (2007)	345.035
3 (2008)	368.374
4 (2009)	397.31
5 (2010)	419.265
The Total Load For All The Feeder In Non-Residential Area For Each Year	
X (Year)	Y (load) in MW
1 (2006)	151.38
2 (2007)	172.56
3 (2008)	184.673
4 (2009)	192.861
5 (2010)	201.02

Table 2: Output values of Software application

Forecast Results (F _t) for Residential Area			
Year	Linear Model	Compound Growth Model	Cubic Model
1 (2006)	298.713	299.24	288.5694
2 (2007)	330.836	327.9	335.9026
3 (2008)	362.959	359.3	373.0954
4 (2009)	395.082	393.7	400.1478
5 (2010)	427.205	431.42	417.0598
Forecast Results (F _t) for Non-Residential Area			
1 (2006)	156.578	146.1	152.3016
2 (2007)	168.536	156.36	170.6812
3 (2008)	180.494	167.34	184.7798
4 (2009)	192.452	179.1	194.5974
5 (2010)	204.41	191.66	200.134

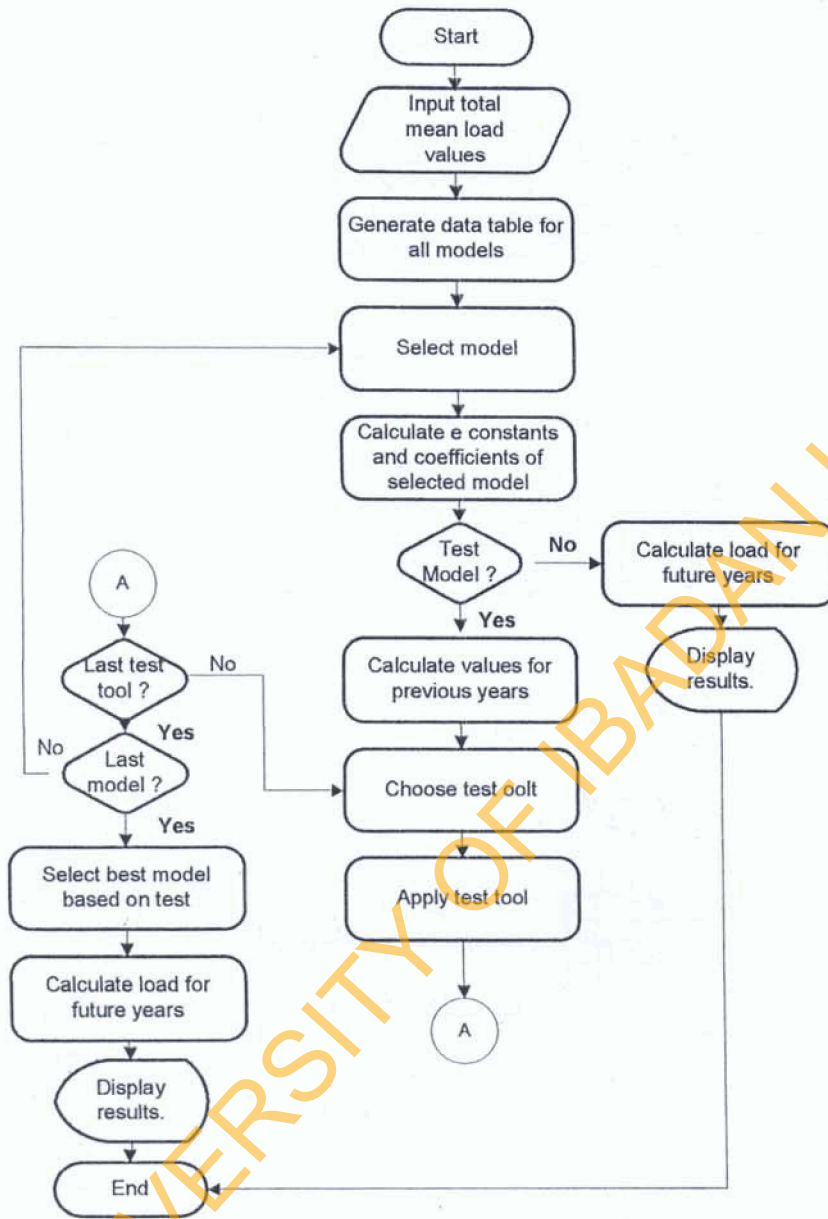
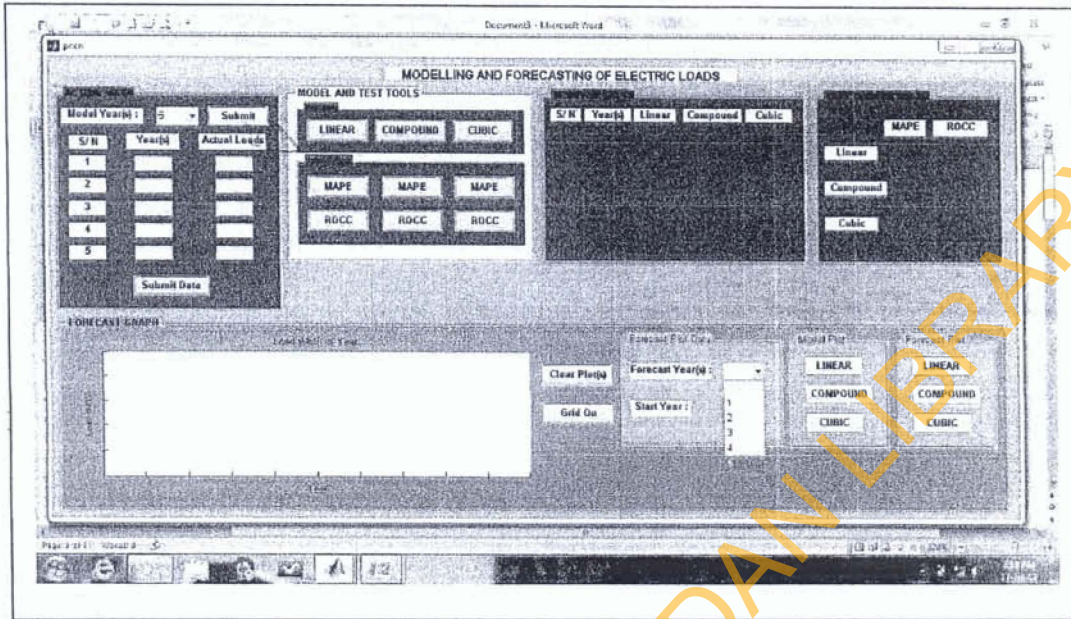
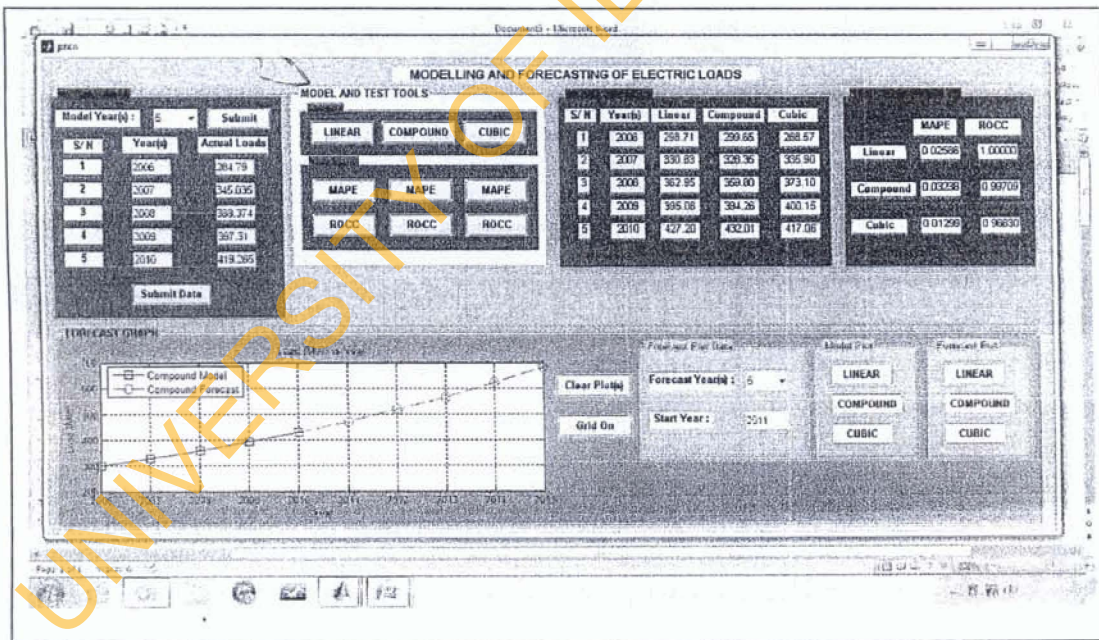


Figure 1: Flow chart of Software Algorithm.



Figures 2: Input Interface of the developed software using.



Figures: 3 Result interface of the developed software.



4.0 RESULTS GENERATION AND VALIDATION

Presented in this section are the results obtained by applying the developed software algorithm on modeling and forecasting electricity load consumption for the case study found in literature (Eneje *et al.* 2012). The values presented in table 2 are the load forecasts calculated by the software. These results are compared graphically with those found in literature. The three categories of result compared are: (i) Energy loads forecasted for the previous years applying the three discussed models for residential and non residential areas (ii) Test tools results using MAPE and rank of correlation coefficient (ROCC) for residential and non residential (iii) Forecasted load values for future year using the most appropriate model based on step (ii) for residential and non residential. The comparison of results in Figs. 4 – 7 validates the accuracy of the developed software. All the results are exactly the same with those found in the literature (Eneje *et al.* 2012). The results of tests done on each model applying the MAPE and ROCC tools are also compared in Tables 1 and 2. The results are of the same values thereby establishing further the reliability of the software.

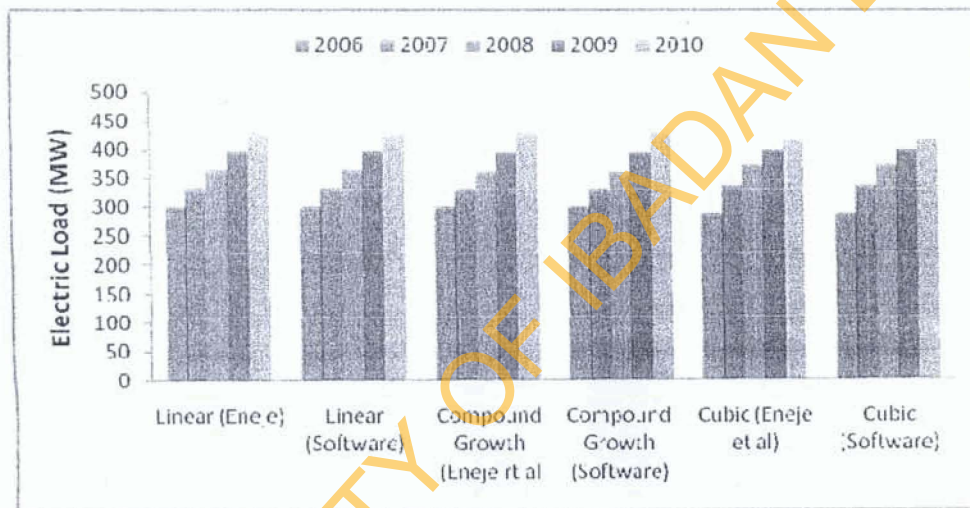


Figure 4: Comparison of Forecast Results for Previous Years in residential Area

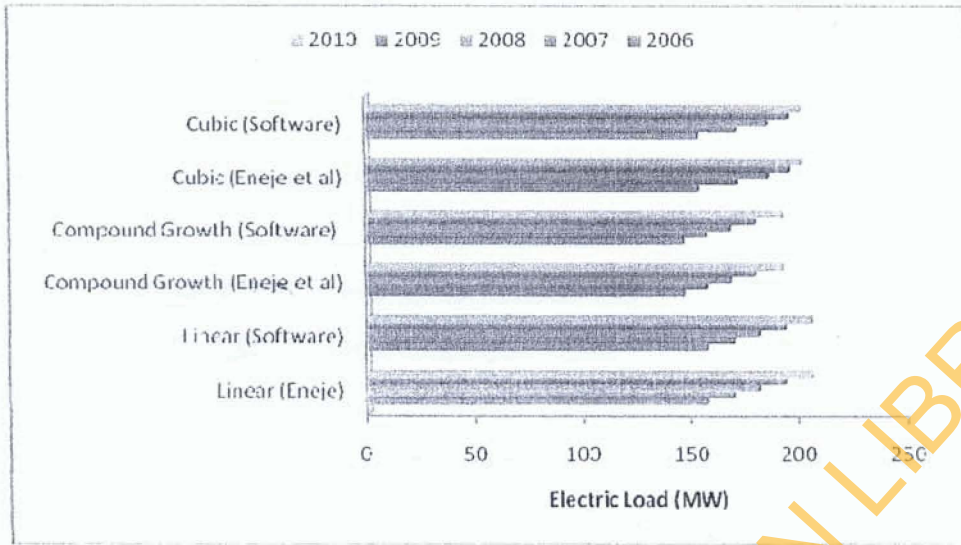


Figure 5: Comparison of Forecast Results for Previous Years in Non-residential Area

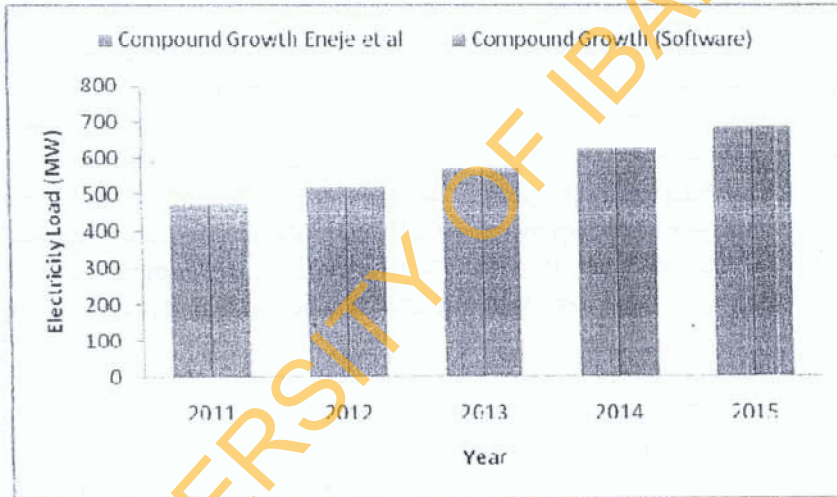


Figure 6: Comparison of Forecast Results for future Years in Residential Area

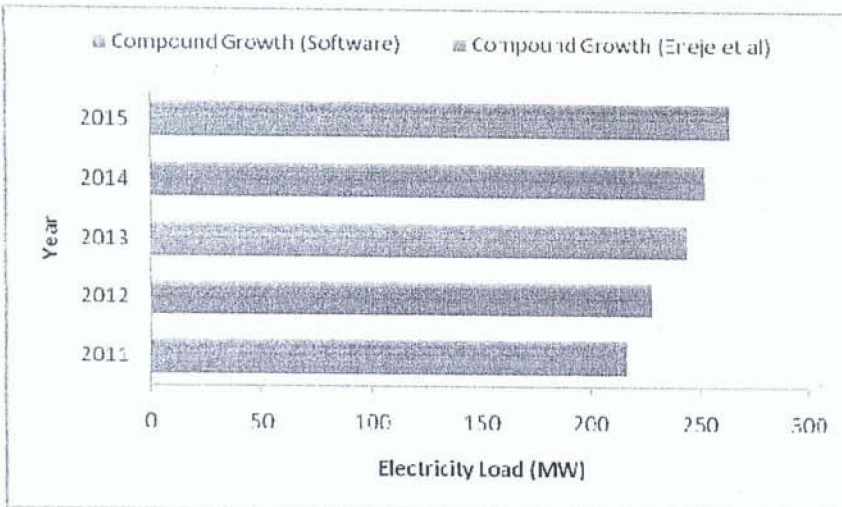


Figure 7: Comparison of Forecast Results for future Years in Non-residential Area

5.0 CONCLUSION

The objective of this work which is to ease the repetitive process of energy modeling and forecasting by developing software using a mathematical and universal language (MATLAB, 2009) has been achieved. This work keeps up with the modern trend in computer-aided engineering and learning practice that can be adapted to solve various engineering problems. The software developed in this work enables the computation of energy loads for extensive period of time, large data and variety of models. The uniqueness of the software lies in its ability to be used as learning and problem solving software. Though three models and two test tools namely, Linear, compound growth, cubic, MAPE and ROCC respectively have been catered for at this present stage, more models as well as other test tools will be added in further works. The results of validation of the software using existing case studies prove the reliability of its application in modeling and forecasting energy loads.

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