wjert, 2018, Vol. 4, Issue 3, 57-64. *Original Article* ISSN 2454-695X

World Journal of Engineering Research and Technology
WJERT
www.wjert.org SJIF Impact Factor: 5.218

FORECASTING ENERGY DEMAND IN CALABAR METROPOLIS FOR SYSTEM PLANNING AND MANAGEMENT

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Article Received on 15/03/2018 Article Revised on 05/04/2018 Article Accepted on 26/04/2018

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ABSTRACT

Electricity use has become an indicator of economic development. Population, technology, economic status of the end-user, temperature, season, and so on, are factors affecting the rate of consumption of/and demand for electricity. Load forecast is used to estimate the total electric energy needed by a household or industry for future purposes. Short, medium and long term periodic measure and estimates are different period of estimating load demand. This information is a prerequisite to good power planning and management, the inadequacy or non-availability of electric energy can be traced to lack or wrong estimates. In this paper the multiple regression method used to predict future energy demand in Calabar Metropolis because it has an error within acceptable range. Accurate models for electric power load forecasting are essential to the operation, planning and management of a utility company. Calabar metropolis is randomly selected as the sample society. When future demand is estimated, the calculated peak load show that energy demand in Calabar Metropolis will be 118.20 MW in 2028. The research finding also show that for electricity supply or generation to meet electricity demand of Nigeria there must be an upward trend increase in power generation, at least 4% increase of the current capacity annually or 40 % within ten (10) years.

KEYWORDS: Energy demand, energy management, load forecast, multiple regression analysis.

1. INTRODUCTION

Electric power is the main source of energy for industrial and social applications. Due to it distinct characteristics of controls and speed of transportation over long distance, it can be produced centrally or in strategic centers controlled and distributed.[1] Though with numerous benefits, yet cannot be stored, therefore there must be a constant supply for immediate use.[2,3] Consumers' electricity demand are timely unpredictable. Power is generated, transmitted and distributed to the end user. The question; what capacity is generated, what capacity is available to the end-user. Often time, the capacity is grossly inadequate, hence, system management and planning. Present task of electric power generation, transmission and distribution are handled by power holding company of Nigeria (PHCN).

Calabar is reputed to be Nigeria's cleanest city and carnival capital, the Cross River State capital. It has made another history by becoming Nigeria's first digital city, following the completion of installation of its metropolitan dark fibre optic network infrastructure. It attracts the patronage of tourists, investors and sporting activities. Human activities and business increasing daily due to the peaceful visitor-friendly city nature of the city, and infrastructure development is on the increase. Calabar host a world class TINAPA Business resort and the Calabar Free Trade Zone with about 28 industries. The city has about 175 Hotels, out of which 15 are world class. Energy demand is rising at alarming rate. It is observed that if nothing is done now, in the near future, the country will be thrown into total darkness. Energy therefore is an essential commodity, making this work is timely and helps for proper planning and management.

2. Load Forecast

Forecasting is the process of making statement about events whose actual outcomes have not yet been observed. It is the basis of decision making. Load forecasting is the projection of electrical load that will be required by a certain area with the use of historical data of electrical energy usage. Forecasting has a wide application which include; energy generation and purchasing; load switching and control, contract evaluation and electric power infrastructure development.[4,5] Since the effectiveness of any power supply is highly dependent on the reliability of distribution, the main aim of this paper is to develop a model to predict future energy demand in Calabar Metropolis in order to meet the distribution planning objectives. Operational decision such as economic scheduling of the generating capacity, scheduling of fuel purchase and system security assessment are based on such forecast.[6] Long term load forecast is related to the weather variability such as temperature and climate changes. A more detailed estimate could consider also parameters like; population growth, price of electricity and related commodities, time and others in the model development. References[7-9] describe others application of regression models applied to load forecasting. According to[2] method 1-4 uses statistical means to arrive at a forecast solution. According to,[10] a method for load forecasting called data mining is adequate to predict future load demand. Date mining is the process that gives information as data in a large database for forecast with predefined rules. Short term load forecast rules are presented in.[11]

Forecasting is used to predict future statistical data from a study of the past behavior of contributing factors. There are three levels of forecasting electric load depending on the time intervals.[8] The levels are termed; Short term load forecasting (STLF), Medium term load forecasting (MTLF), and Long term load forecasting (LTLF). Short term load forecasting covers one hour to one year and is mainly used for power system operation studies, losses reduction, voltage regulation, unit commitment and minimization of revenue of the utility.[6,8] Medium term load forecast (MTLF), cover a period of two to three years and Long term load forecast (LTLF) covers a period from ten years and above.[3,12] This paper presents a long term load forecast, that is, 10 years. It aids adequate scheduling and operation of power system and management. For accurate management of electric utilities, long term load forecast is very important.[5,8,13]

Christensen, et al in[6] presented a regression-based daily peak load forecasting method with a transformation technique. This method uses a regression model to predict the nominal load and a learning method to predict the residual load. In,[14] this model was expanded by introducing two trend processing techniques designed to reduce errors in transitional season. Trend cancellation removes annual growth by subtraction or division, while trend estimation evaluates growth by the variable transformation technique as detailed in.[15] According to[16] least squares approach can be used to identify and quantify the different types of loads at power lines and substations.

Weather-load model were presented in,[17] to predict load demand for the electricity supply system using the effect of weather, the model was developed using regression analysis of historical load data. Later developed and adaptable regression model for 1-day-ahead of forecasts, which identifies weather-insensitive and-sensitive load components. Linear regression of past data is used to estimate the parameters of the two components. Hamadi in[18] used new regression based method, Nonlinear load Research Estimator (NLRE) to forecast load for four substations, customer class, month and type of day.

Scolt in[19] developed a regression model of electric energy consumption in Eastern Saudi Arabia as a function of weather data, solar radiation, population and per capita gross domestic product. Variable selection is carried out using the stepping regression method, while model adequacy is evaluated by residual analysis.

The non-parametric regression model[17] constructs a probability density function of the load and the load effecting factors. The model produces the forecast as a conditional expectation of the load given the time, weather and other explanatory variables, such as the average of past actual loads and the size of the neighborhood. Regression based on daily peak load forecasting method for a year including holidays is presented in.[4] To forecast load precisely throughout a year, different seasonal factors that affect load differently in different seasons are considered. In the winter season, average wind chill factor is added as an explanatory variable in addition to the explanatory variables used in the summer model. In transitional seasons such as spring and fall, the transformation technique is used. Holiday effect load is deducted from normal load to estimate the actual holiday load data. This model contains some deterministic influence such as average load and exogenous influence such as weather. The method is based on hybrid techniques of optimal regression and artificial neural network. It classified the load ranges into several classes, and decides where the forecasted load belongs, according to the classification rules and the multi- layer perception (MLP) used to train the sample in every class.[17,19]

3. Multiple Linear Regression Model

A linear regression shows the relation between the dependent variable y and the independent variable x,

$$Y = a_0 + a_1 x_1 \qquad (1)$$

Using the least squares method, the best fit line can be found by minimizing the sum of the squares of the vertical distance from each data point on the line. Multiple linear regression model depends on the numbers of variable and is related to two or more independent variables. The general model is of the form equation (2) as in.[3]

$$Y = a_0 + a_1 x_1 + a_2 x_2 + a_3 x_3 \qquad (2)$$

The model in equation (2) has to be minimized so that one can find the values of the four co-efficient. First we compute the difference, differentiation of the sum of the squares of these differences and calculation of the constant for the system of equations produced by setting the partial derivatives equal to zero, the resulting equations becomes:

$$n_{a0} + a_1 \sum_{i-1}^{n} x_1 + a_2 \sum_{i-1}^{n} \quad x_{21} = \sum_{i-1}^{n} y_1 \qquad (3)$$

$$a_0 + a_1 \sum_{i-1}^{n} x_{1i} + a_1 \sum_{i-1}^{n} + x_{1i}^2 + a_2 \sum_{i-1}^{n} = \sum_{i-1}^{n} x_1 y_1 \qquad (4)$$

$$a_0 + a_1 \sum_{i-1}^{n} x_{2i} + a_1 \sum_{i-1}^{n} + x_{1i} x_{2i} + a_2 \sum_{i-1}^{n} x_{2i}^2 = \sum_{i-1}^{n} x_{21} y_1 \qquad (5)$$

4. PRESENTATION AND DISCUSSION OF RESULT

Applying the model equation in MATLAB, the resulting values of the coefficient a_0, a_1, a_2 and a_3 are obtained as a_0 = -190.0887, a_1= -3.4480, a_2= 0.5012 and a_3= 215.0250.

By substituting the values of a_0, a_1 , a_2 , a_3 and the error into equation (2), the model equation which is the least square fit of the data is related to multiple regressions for Y and the inputs variables x_1, x_2, and x_3 becomes:

$$Y = 215.0250x_3 + 0.5012x_2 - 3.4480x_1 - 190.0887 + \text{error} \qquad (6)$$

Table 1: Load calculated with error and the available load.

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Available Load(MW)	39.1	41.1	38.7	43.2	57.6	64.7	66.5	59.0	63.8	65.3
Calculated Load (MW)	47.78	51.11	54.38	57.12	60.18	64.99	68.96	70.96	74.47	79.71

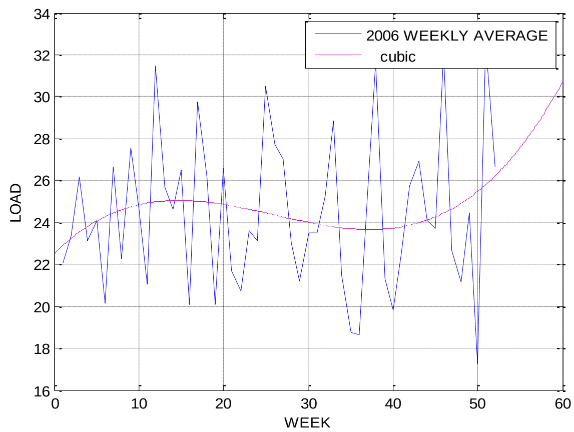

Fig. 1: Graph of load (MW) against time (week) considering weekly average.

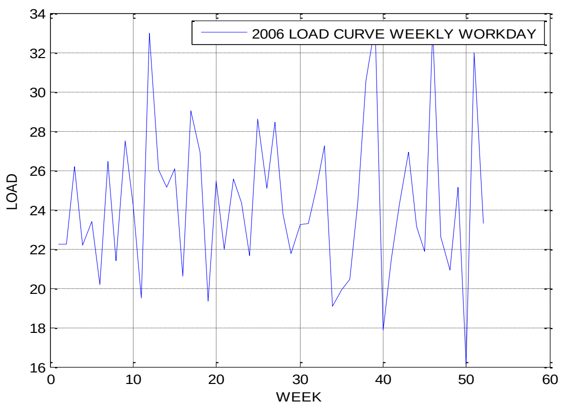

Fig. 2: Graph of load (MW) against time (week) considering workday average.

The figure 1, 2 and 3, 4, shows weekly and daily load variation. The peak demand variation from week and day to day can be observed in the figures. Thus depicting the effect of the parameters used on load consumption. The load forecasted for the period of ten years is shown in table 1. The load demand is expected to increase at a certain level every year as it is shown in the table 1 above.

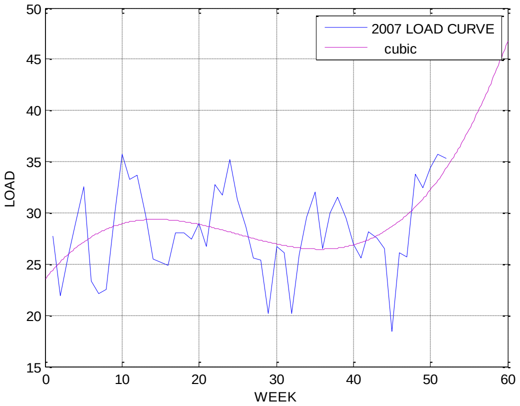

Fig. 3: Graph of load (MW) against time (week) considering weekly average.

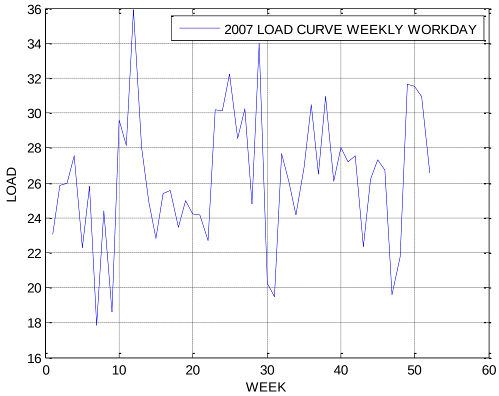

Fig. 4: Graph of load (MW) against time (week) considering workday average.

Table 2: Year and calculated load.

Year	Load (MW)
2016	81.38
2017	85.88
2018	88.53
2019	91.54
2020	98.74
2021	100.55
2022	106.54
2023	108.20
2024	111.70
2025	118.70

The figure 1, 2 and 3, 4, shows the weekly and daily average load variation. The locations of peak loads are not static but rotating from one week to the other. Thus, it depends on the effect of the parameters used on load consumption. The load forecasted for the period of ten years is shown in table 1. The load demand is expected to increase at 4% annually or about 44% every Ten (10) years. Thus, the calculated and the predicted load agrees favorably.

CONCLUSION

Long term load forecast is for effective planning and management of electricity in the utility companies. Multiple regression method is used to estimate load demand in 10 years from date, and the result shows that, there will be an increase in energy demand within this period and always. As long human activities continues, electricity demand continue to increase, this increase ought to be met with additional increase in power generation and system update. The research findings suggest that the power operators develop strategy for adequate energy availability to sustain and meet the expected future energy demand, in this case 118.20 MW annually for Calabar Metropolis.

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