Analysis Of Nigeria's National Electricity Demand Forecast (2013-2030)

Ezennaya O. S., Isaac O. E., Okolie U. O., Ezeanyim O. I. C.

Abstract: with increasing dependence on agriculture, industries and day-by-day household comfort upon the continuity of electric supply from PHCN systems in Nigeria, the forecast of electrical demand have assumed a great importance. For electricity supply not to be an cog in the wheel of progress of the Nigerian economy and perhaps a snag in the attainment of the millennium development goal MDGs load forecasting must be performed to coordinate electricity demand and supply. This research work focuses on Nigeria electricity demand forecast from 2013-2030 towards vision 2025 using Time Series Analysis on past load demand.

Index Terms: Commercial demand, Electricity demand, Energy generation, Electricity supply, Energy consumption, Forecast, Industrial demand, Load demand, Residential demand,

1 INTRODUCTION

POwer holding company of Nigeria (PHCN) was empowered to generate coordinate and maintain the economic system of electricity supply to all the nooks and crannies of the nation. That propelled the nation's technological and industrial growth. PHCN has become the fastest and biggest growing electricity industry in Africa and indeed the developing world with an average consumer population of about sixty million [1]. It is very important to recognize that the forecast of power demand in nigeria must be performed during and as an integral part of the power system design process. it is not practical to add the load forecast at a latter date and an attempt to do so could prove unrewarding and involves considerable and unnecessary cost even if it is physically possible. Load forecasting is needed to coordinate transmission and distribution outages over the system and reduce system failure rate. the later section of this paper focuses on the long term load forecasting of Nigeria electricity demand, and the method of forecasting employed is the stochastic/probabilistic extrapolation method which based on the time series analysis of past load demand curve using straight line graph/curve (y = a + bt).such forecast helps in making decisions aimed at correcting the imbalance between the power generation and consumption thus leading to greater network reliability and higher power quality. The aim of this paper is to determine the nature of Nigeria electricity load demand, plan for future expansion of the current network and determine the economic distribution of load between the available generating stations to meet the load demand.

This study is essential to be able to predict /forecast the quantity of power needed by Nigeria owing to the epileptic nature of the Nigerian power supply and plan future network expansion, reduce cost of energy generation, stop load shedding and reduce power outages to minimum. It is important to recall that one of the main focuses of the present government (7point agenda) is steady power supply throughout the nation which is part of the strategies mapped out by late President Umaru Musa Yar'adua and yet carried on by President Goodlock Ebele Jonathan in other to meet the vision 2020 and 2025 respectively. The information obtained will help the federal government of Nigeria to regularize the irregularities in her power system, as well as help the students' personal development in power system planning and control. Remedies for constraints which limit the Power Holding Company of Nigeria from proving power to its teaming consumers are therefore presented using the existing network.

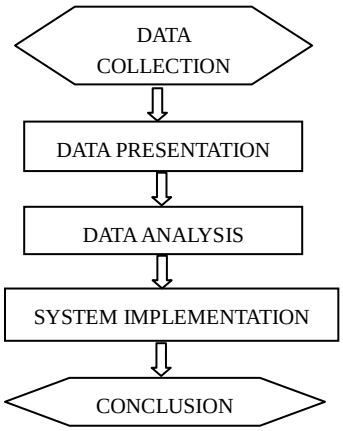

Fig.1: Block diagram

1.1 Load Prediction Technique based on past load data

I. Deterministic (correlation) method

When past load data is correlated with macroeconomic variables such as Gross National Product (GDP),population growth etc., it becomes an econometric model.With this correlation method, the historic demand are correlated with selected consumer characteristics and from the expected changes in these, a load growth is estimated [2].

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II. Stochastic/probabilistic extrapolation method

This method is based on the time series analysis of the load demand curve by means of regression models. In this method suitable mathematical curve such as; Straight line graph $y = a + bx$, Logarithmic curve $y = ax^b$,Parabolic curve $y = a + bx^2$, Exponential curve $y = ae^{bx}$ are fitted to the trend of the load demand by means of least square method.The resulting trend line (curve) is extrapolated to the future using the trend value and the projected load demands are obtained.

1.2 Load Demand Pattern in Nigeria

I. Daily Load Demand

The daily load demand pattern in Nigeria is divided into OFF-PEAK and PEAK periods [2]. The off peak period lasts for about fifteen hours and this is the period of minimum load demand of the day. The first off-peak periods occurs in the morning between 0000hrs- 0500hrs during this period most of the commercial centers, club homes and other recreational places are shut down for the day. The second off-peak period occurs between 0800hrs-1800hrss, during this period the residential power consumption drops as most have all left for offices and industries, the commercial and industrial loads predominates at this period. The first peak period occurs between 0500hrs-0800hrs when people wake up in preparation for the day's activities and as such so many home appliances are switched ON. The second peak period occurs between 1800hrs-2400hrs and this is the period that people return from their respective places of work and put so many electrical appliances into use.

II. Weekly Load Demand

In Nigeria, weekly load demand follow a specific pattern, it is higher at week days when factories and most commercial centers are in operation and lower in weekends when most of them are shut down making the residential load to predominate.

II. Annual Load Demand

Annual power consumption pattern varies between hot/dry and rainy seasons. Maximum peak demand occurs between January and April when the weather is extremely hot and dry. Minimum annual load demand occurs between June and September, mid-November and early January with extreme wet period of the year and harmattan period respectively when most heavy loads like air conditioners are switched off. The daily and weekly load forecast fall under short-term load forecast while the annual load forecast fall under long-term load forecast.

2 METHODS AND DATA PRESENTATION

2.1 Time Series Analysis

Time series analysis is a widely used statistical method used in the task of peeing into the future. Time series analysis deals with the statistical technique of analyzing past data and projecting them to obtain estimates of future values. We therefore define time series as a series of observation recorded over a period of time [3].

2.2 Uses of Time Series

1. It helps to predict or forecast the behavior of a variable in future.
2. It helps in the analysis of past behavior of a variable.
3. It helps in comparative studies in the value of different variables at different times or places.

2.3 Types of Time Series

1. Demographic time series; these deals with the study of natural population in a geographical location at a specific period of time. Such data as number of births, deaths morbidity, marriage divorces, migration etc., over a period of time.
2. Economic time series; these deals with series of data that has direct influence of the economy of a place. Example, electricity generation, electricity consumption, production, imports, exports, expenditure, income, profits etc., over a period of time.
3. Physical time series; data such as rainfall, humidity, temperature, wind, cloud cover etc. per day over a period of time are examples of physical time series data.
4. Marketing time series; this relates to economic time series, it studies the behavior of finished products in the market in terms of sales.

2.4 Time Series Analysis

1. SECULAR TREND; the trend of a time series is the smooth upwards or downwards movement of a time series over a long period. The trend gives a picture of the general tendency in the development of a process [4]. In other words, the trend characterizes the general and consistent pattern of changes in a time series. The pattern of trend can be linear or curvilinear [5]. The growth pattern which characterizes the gradual increase ordecrease in the magnitude of the variables is described by a straight line. Other forms can be described with various kinds of curves like parabola, hyperbola etc.
2. SEASONAL VARIATION (COMPONENT); these are periodic variations that occurs with some degree of regularities within a specific period of one year or less. Such repetitive seasonal fluctuations are usually caused by seasons, weather, social customs, religious festivities etc. Seasonal patterns are primary concern because not much intelligent planning or scheduling can be done without a good understanding of the seasonal patterns and statistical measures thereof.
3. CYCLICAL VARIATIONS; the cyclical variation correspond to the business cycle, that is, the occurrence of the UP and DOWN (boom and depression) movements of a business activity from some sort of statistical trend. The cyclical variations remain in the time series after the trend, seasonal variations and irregular fluctuations have been eliminated.
4. IRREGULAR VARIATIONS; these are sometimes referred to as erratic fluctuations of a time series. They are usually of short duration and follow non-regular or systematic pattern. Sometimes they produce long lasting and serious effects. They may be unpredictable or may result from isolated special occurrences as

good or bad news, wars, strikes, floods, earthquakes, drought, global financial crisis etc.

The cyclical variations and irregular variations are not easily described by mathematical models and are sometimes referred to as Residual variations [6]. Any of these models could be assumed for a time series:

i. Multiplication model $Y_t = T \times S \times C \times I$
ii. Additive model $Y_t = T + S + C + I$

Where;Y_t = the value of the variable at a particular time, S = the seasonal variation, T = the trend, C = the cyclical variation, I = Irregular variation.

2.5 Time Series Analysis

The estimation of the trend of a time series starts with plotting the time series data on a graph. The resulting scatter diagram suggests the appropriate trend line to fit the data. If the points follow closely a straight line trend has to be fitted in the data. The trend line can be found by using; the free hand method, the method of moving average, the least square method and the semi-average method.

I. The Free Hand Method

When the time series is plotted on a graph, a straight line is fitted through the plotted points by inspection. The advantage of the free hand method of fitting is that it is easy to use and it provides a quick description of the general tendency in time series. The problem with this method is that it is subject to individual Judgment of the person fitting the line.

II. The Method of Moving Average

This is a technique of smoothening out erratic (random) fluctuations in the time series. Suppose we have time series data, a three year moving average can be gotten by averaging the values first of period 1 – 3, then period 2 – 4, period 3 – 5, and so on. These averages are assumed to represent the trend values. Each value is the middle of the period it relates to. In cases where periods being averaged have even number of terms, say 4year moving average it would be appropriate to compute another 2-period moving averages to center the moving averages at periods rather than have them between periods. To determine the order (periods) of a moving average all we need do is observe the data over the years.If it is found, for instance that the figure seems to come to a peak every three years, then a three year moving average would be appropriate. The longer the length of period the smoother the resulting series and the more information are lost at the beginning and the end of the series.

III. The Least Square Method

This method is used in fitting trend line to a time series. It is the most widely used method of finding the trend. The linear trend equation is given as; $Y_t = a + bt$

Where;Y_t= the estimated trend value for a given time period t, a = the trend line value when t = 0, b = the gradient or slope of the trend line, i.e. the change in Y_t per unit time, t = the time limit. The estimates of the parameters of the trend equation are 'a' and 'b'and they are obtained by solving the following normal equations; $na + b\sum t = \sum y$ and $a\sum t + b\sum t^2 = \sum ty$ Where; n =number of years under consideration. It can also be obtained from the values of 'a' and 'b' by minimizing the sum of squares of error. Formula for the parameter estimates are; $a = \frac{\sum y}{n} - \frac{b\sum t}{n}$ and $b = \frac{n\sum ty - \sum t \sum y}{n\sum t^2 - (\sum t)^2}$

2.6 Estimation of Seasonal Variation

The study of seasonal variation is important because it helps to determine the effects of season on the value of the variable. The elimination of seasonal variation enables us to study what would have been the value of the variable if there is no seasonal influence. For study of seasonal variation the data must be given for part of a year such as months quarterly weekly etc. The seasonal component is not considered in this paper since the data is given in yearly.

2.7 Measuring Accuracy of Forecast

The accuracy of forecast can be measured either by using; the mean Absolute Deviation (MAD) or the sum of square error.

MAD = $MAD = \frac{\sum(Actual - forecast)}{n}$

$SSE = \sum(Actual - Forecast)^2$

The smaller the value of MAD and SSE, the more accurate the forecast model used [4].

2.8 Data Source and Presentation

The data used in this paper covers electrical energy consumption in Nigeria from 2000 – 2012 broken down into three categories, residential, commercial and industrial. They were collected from the National Bureau of Statistics and the Central Bank Statistical Bulletin.

Table 1: Table of Energy Consumption (MW)

	ENERGY CONSUMPTION (MW)			
YEAR	INDUSTRIAL	COMMERCIAL	RESIDENTIAL	TOTAL
2000	1011.60	2346.00	4608.40	8688.90
2001	1987.20	2439.00	7714.80	9034.40
2002	1830.00	3297.60	7668.50	12842.40
2003	1659.80	3583.00	7668.50	12866.60
2004	1605.00	3830.30	7725.30	13160.60
2005	1615.50	3851.00	7760.00	13226.60
2006	1575.00	3900.80	7650.00	13125.80
2007	1530.50	3915.00	7860.30	13305.80
2008	1502.50	3852.00	7910.08	13264.55
2009	1585.00	3865.50	8075.00	13525.50
2010	1589.40	3925.80	8205.20	13720.40
2011	1615.50	4004.70	8285.60	13905.80
2012	1648.00	4025.40	8350.00	14023.40

Source: Central Bank of Nigeria STATISTICAL BULLETIN and National Bureau of Statistics (NBS).

3 DATA ANALYSIS

3.1 Residential Forecasts

The residential demand forecast is performed using the data below:

Table 2: Table of Residential Demand Forecast

Year	T	Residential demand(MW) y	ty	t^2
2000	-6	4608.40	-27650.40	36
2001	-5	7714.80	-38574.00	25
2002	-4	7668.50	-30674.00	16
2003	-3	7668.50	-23005.50	9
2004	-2	7725.30	-15450.60	4
2005	-1	7760.00	-7760.00	1
2006	0	7650.00	0.00	0
2007	1	7860.30	7860.30	1
2008	2	7910.008	15820.16	4
2009	3	8075.00	24225.00	9
2010	4	8205.20	32820.80	16
2011	5	8285.60	41428.00	25
2012	6	8350.00	50100.00	36
Total	0	99481.68	29139.76	182

From $Y = a + bt$

Where; a = $\frac{\sum y}{n} - \frac{b\sum t}{n}$ = trend line value when t = 0, b = $\frac{n\sum ty - \sum t\sum y}{n\sum t2 - (\sum t)2}$ = gradient of the trend line

Therefore; $Y = 7652.43 + 160.10t$; *the trend values are given below:*

Table 2: Trend Values

Year	Residential Demand(MW) y	Trend value Y (MW)
2000	4608.40	6691.83
2001	7714.80	6851.93
2002	7668.50	7012.03
2003	7668.50	7172.13
2004	7725.30	7332.23
2005	7760.00	7492.33
2006	7650.00	7652.43
2007	7860.30	7812.53
2008	7910.05	7972.63
2009	8075.00	8132.73
2010	8205.20	8292.83
2011	8285.60	8452.93
2012	8350.00	8613.03
Total	99481.68	99481.59

I. Calculating the Accuracy of Residential Forecast

The Mean Absolute Deviation $MAD = \frac{\sum(Actual\ -Forecast\ )}{N} = 6.92 * 10^{-3}$

II. Predicted Residential Demand

The forecast value is gotten by either adding the trend line value (160.10MW) to the preceding load demand to get the current years forecast demand or by using the trend equation [7] to give the table below;

Table 3: Table of Predicted Residential Demand Values

Year	Residential Forecasted Demand Y(MW)
2013	8773.13
2014	8933.23
2015	9093.33
2016	9253.43
2017	9413.53
2018	9573.63
2019	9733.73
2020	9893.83
2021	10053.93
2022	10214.03
2023	10374.13
2024	10534.23
2025	10694.33
2026	10854.43
2027	11014.53
2028	11174.63
2029	11334.73
2030	11494.83

3.2 Commercial Demand

The commercial input chart is given in table 4 below:

Table 4: The Commercial Input Chart

Year	T	Commercial Demand (MW) y	ty	t^2
2000	-6	2346.00	-14076.00	36
2001	-5	2439.00	-12195.00	25
2002	-4	3297.60	-13190.40	16
2003	-3	3583.00	-10749.00	9
2004	-2	3830.30	-7660.60	4
2005	-1	3851.00	-3851.00	1
2006	0	3900.80	0.00	0
2007	1	3915.00	3915.00	1
2008	2	3852.00	7704.00	4
2009	3	3865.50	11596.50	9
2010	4	3925.80	15703.20	16
2011	5	4004.70	20023.50	25
2012	6	4025.40	24152.40	36
Total	0	46836.10	21372.60	182

The gradient of the trend line $b = \frac{n\sum ty - \sum t\sum y}{n\sum t2 - (\sum t)2} = 117.43$

Trend line value when t = 0: $a = \frac{\sum y}{n} - \frac{b\sum t}{n} = 3602.77$

Trend equation $Y = a + bt = 3602.77 + 117.43t$

The trend values from the above equation gives the values actual commercial demand and is given in the table below:

Table 5: Table of Values for Actual Commercial Demand

Year	Commercial Demand y (MW)	Trend value Y (MW)
2000	2346.00	2898.19
2001	2439.00	3015.62
2002	3297.60	3133.05
2003	3583.00	3250.48
2004	3830.30	3367.91
2005	3851.00	3485.34
2006	3900.80	3602.77
2007	3915.00	3720.20
2008	3852.00	3837.63
2009	3865.50	3955.06
2010	3925.80	4072.49
2011	4004.70	4189.92
2012	4025.40	4307.35
Total	46836.10	46836.01

I. Calculating the Accuracy of Commercial Forecast

The Mean Absolute Deviation MAD $= \frac{\sum(\text{Actual}-\text{Forecast})}{\text{N}} = 6.92 * 10^{-3}$MW

II. Predicted Commercial Demand

The trend line value (117.43MW) will used to forecast the load demand up to 2030 by adding it to the preceding load to get the load for the next year as shown below.

Table 6: Table of values for Commercial Demand Forecasted

Year	Commercial Demand ForecastedY(MW)
2013	4424.78
2014	4542.21
2015	4659.64
2016	4777.07
2017	4894.50
2018	5011.93
2019	5129.36
2020	5246.79
2021	5364.22
2022	5481.65
2023	5599.08
2024	5716.51
2025	5833.94
2026	5951.37
2027	6068.80
2028	6186.23
2029	6303.66
2030	6421.09

3.3 Industrial Demand

Table 7: Table of Values for Industrial Demand

Year	t	Industrial Demand (MW) y	ty	t^2
2000	-6	1011.60	-6069.60	36
2001	-5	1987.20	-9936.00	25
2002	-4	1830.00	-7320.00	16
2003	-3	1659.80	-4979.40	9
2004	-2	1605.00	-3210.00	4
2005	-1	1615.50	-1615.50	1
2006	0	1575.00	0.00	0
2007	1	1530.50	1530.50	1
2008	2	1502.50	3005.00	4
2009	3	1585.00	4755.00	9
2010	4	1589.40	6357.60	16
2011	5	1615.50	8077.50	25
2012	6	1648.00	9888.00	36
Total	0	20755.00	483.10	182

Gradient of the trend line $b = \frac{\text{n}\sum\text{ty}-\sum\text{t}\sum\text{y}}{\text{n}\sum\text{t2}-(\sum\text{t})2} = 2.65, a = \frac{\sum\text{y}}{\text{n}} - \frac{\text{b}\sum\text{t}}{\text{n}} = 1596.53$

Trend equation $Y = a + bt = 1596.53 + 2.65t$

The trend values and actual Industrial demand are shown in table 8 below;

Table 8: Table of Values for Actual Industrial Demand

Year	Industrial Demand y(MW)	Trend value Y(MW)
2000	1011.60	1580.63
2001	1987.20	1583.28
2002	1830.00	1585.93
2003	1659.80	1588.58
2004	1605.00	1591.23
2005	1615.50	1593.88
2006	1575.00	1596.53
2007	1530.50	1599.18
2008	1502.50	1601.83
2009	1585.00	1604.48
2010	1589.40	1607.13
2011	1615.50	1609.78
2012	1648.00	1612.43
Total	20755.00	20754.89

I. Calculating the Accuracy of Industrial Forecast

The Mean Absolute Deviation $MAD = \frac{\sum(Actual\ -Forecast\ )}{N} = 8.46 * 10^{-3} MW$

II. Predicted Industrial Demand

Using the trend line value of 2.65MW, we forecast for the future industrial load demand as shown in the table below:

Table 9: Table of Forecast Values for the Future Industrial Load demand

Year	Industrial Forecasted Demand Y(MW)
2013	1615.08
2014	1617.73
2015	1620.38
2016	1623.03
2017	1625.68
2018	1628.33
2019	1630.98
2020	1633.63
2021	1636.28
2022	1638.93
2023	1641.58
2024	1644.23
2025	1646.88
2026	1649.53
2027	1652.18
2028	1654.83
2029	1657.48
2030	1660.13

3.4 Total Predicted Demand

The total Predicted demand is gotten by summing the individual demand forecast of residential, commercial and industrial. The table is shown below;

Table 10: Total Predicted Load Demand

Year	Predicted Load Demand(MW)
2013	14812.99
2014	15093.17
2015	15373.35
2016	15653.53
2017	15933.71
2018	16213.89
2019	16494.07
2020	16774.25
2021	17054.43
2022	17334.61
2023	17614.79
2024	17894.97
2025	18175.15
2026	18455.33
2027	18735.51
2028	19015.69
2029	19295.87
2030	19576.05

4 SYSTEM IMPLIMENTATION

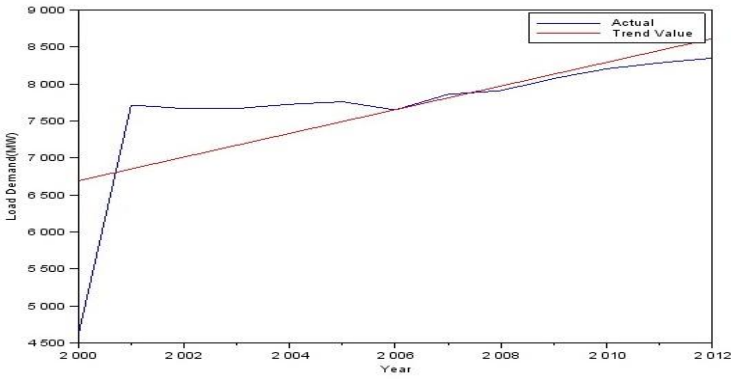

Fig.1: Graph of Nigeria actual residential load demand and trend values from 2000– 2012

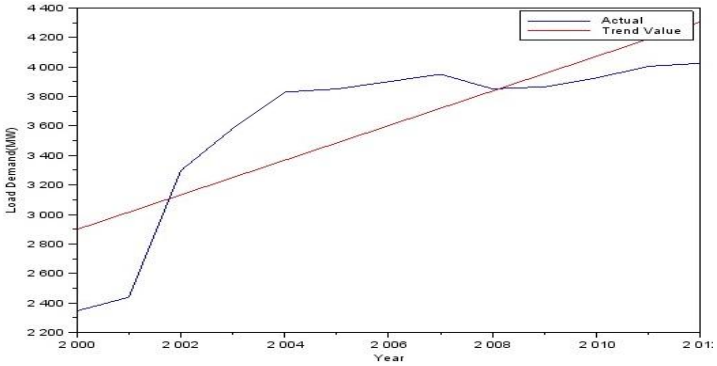

Fig.2: Graph of Actual commercial load demand and Trend values 2000– 2012

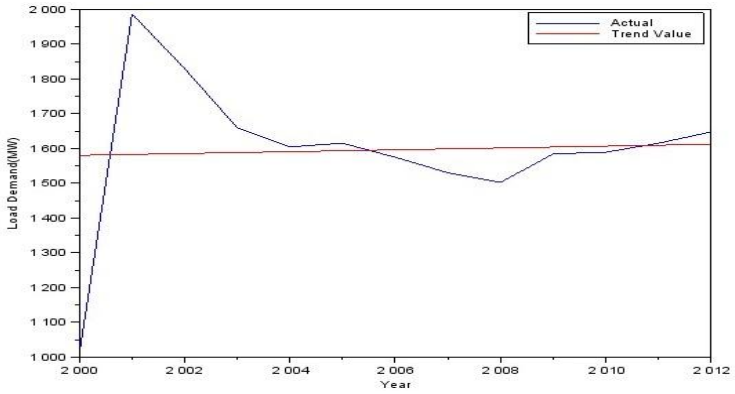

Fig.3: Graph of Nigeria Actual Industrial demand and Trend value from 2000– 2012

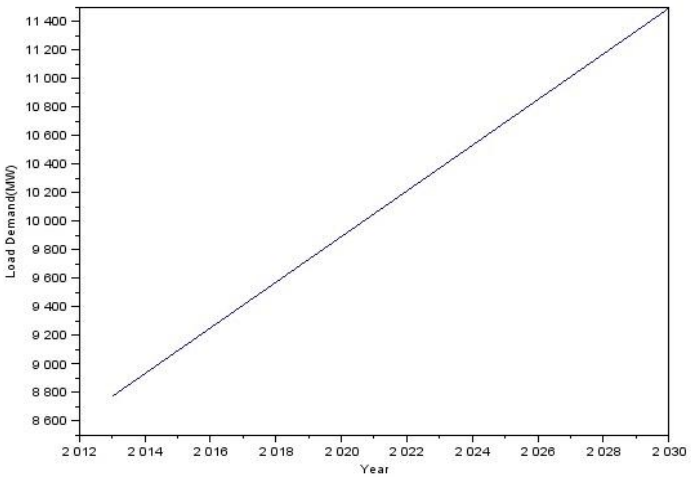

Fig.4: Predicted Nigeria Residential load Demand 2012-2030

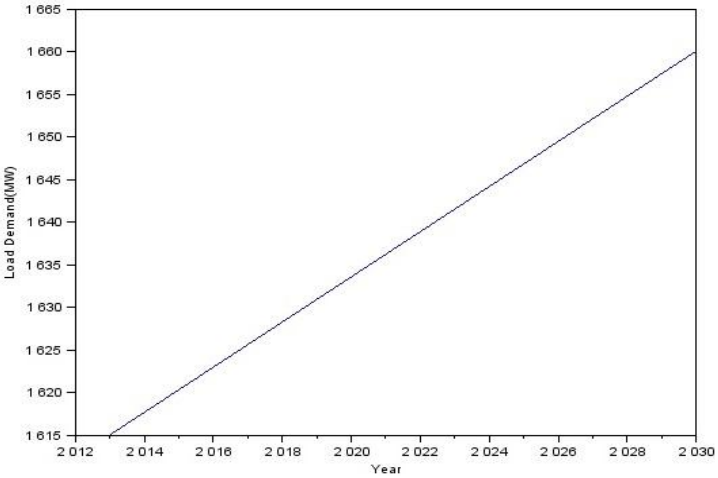

Fig.5: Predicted Nigeria Industrial load demand 2012-2030

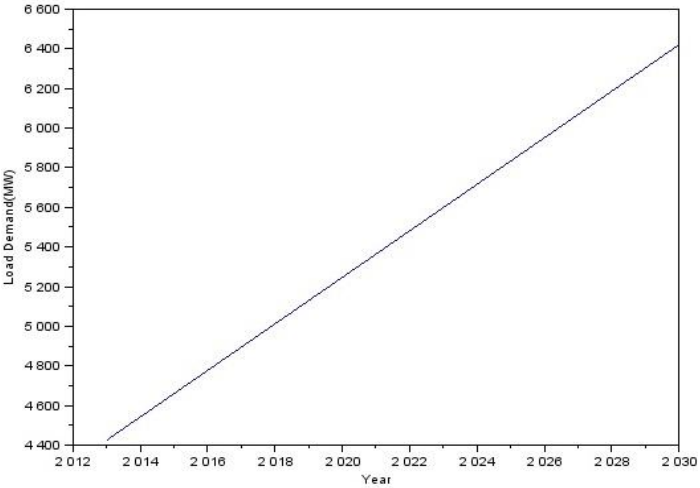

Fig.6: Predicted Nigeria Commercial load demand 2012-2030

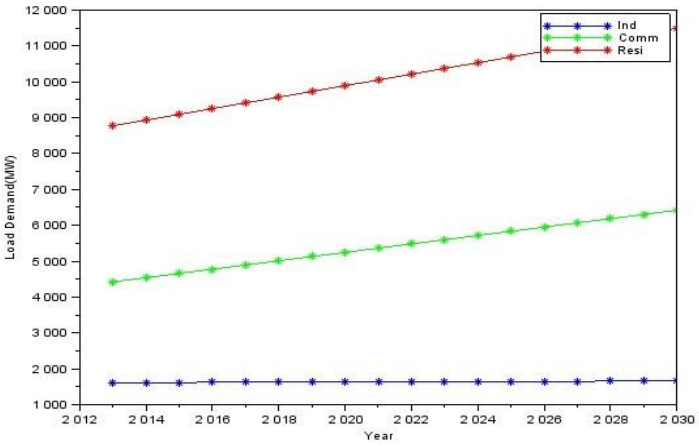

Fig.7: Nigeria predicted Load 2012-2030

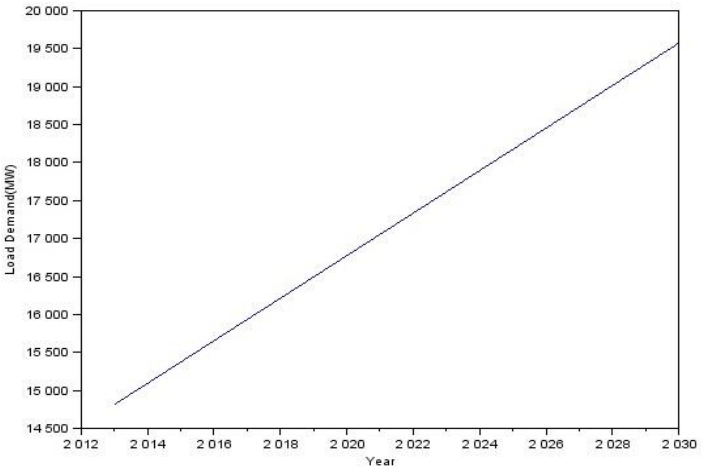

Fig.8: Nigeria predicted Total Load 2012-2030

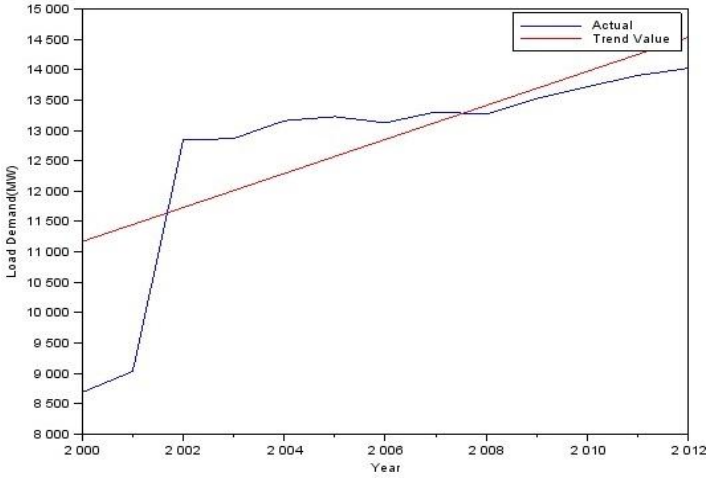

Fig.9: Nigeria Actual Load Demand and Trend Values from 2012-2030

5 CONCLUSION

Electricity supply in Nigeria is grossly inadequate, total installed capacity is far less than the demand and out of this installed capacity the available capacity is barely above half of the installed capacity. The per capita energy consumption is too low for meaningful economic and social development. In spite of this, Nigeria still has a constraint of supplying 70MW of

energy to Niger Republic. Therefore, for the country to meet the Millennium Development Goals (MDGs), the Power Holding Company of Nigeria (PHCN), the Nigeria Electric Regulatory Commission (NERC) and the Federal Government should work towards generating or importing about 20,000MW of electricity which is about 300% of the present installed capacity.

REFERENCES

[1]. **S.A. Sambo,** "Electricity Demand from Customers of INGA Hydropower Projects:The Case of Nigeria"Paper presented at the WEC Workshop on Financing INGA Hydropower Projects, pp. 21-22, London, U.K., Apr. 2008.

[2]. **M.N. Eleanya, O.A. Ezechukwu, and B.I. Ofurum,** "Problems of Transmission and Distribution Network: Nsukka as a test case" International journal of Electrical & Telecommunication Systems Research (Electroscope), pp. 126-130, Nov. 2007.

[3]. **I.E. Jude, E.O. Micah, and N.J. Edith,** "Statistics and Quantitative methods for construction and Business Managers" Nigeria institute of building, pp. 1-6, Nigeria, Jan/Feb. 2005.

[4]. **R. S. Murphy, and J. S. Larry,** "Theory and Problems of Statistics", Third edition. Pp.280, McGraw-Hill 1999.

[5]. **B.R. Gupta,** "Power system Analysis and Design", S. Chand & Company Ltd Ram Nagar, pp. 260-274, New Delhi, India, 2007.

[6]. **http://www.Wikipediafreeencyclopedia.com**"Electri city Demand Forecast Review June 2006 case study England".

[7]. **Central Bank of Nigeria STATISTICAL BULLETIN** (vol. 15, 16& 17) November 2006, December2009 &2012 and **National Bureau of Statistics (NBS**), Abuja Nigeria Dec. 2008

[8]. **G.A. Adepoju, S.O.A. Ogunjuyigbe, and K.O. Alawode,** "Application of Neural Network to Load Forecasting in Nigerian Electrical Power System", Pacific Journal of Science and Technology. Iss.8 Vol.1 pp. 68-72, 2007.

[9]. **A.G. Bakirtzis, V. Petridis, S.J. Kiartzis, M.C. Alexiadis, and A.H. Maissis, "**A Long Term Load Forecasting Model for Greek Power Systems", IEEE Transactions on Power Systems, Iss.11 pp. 858-863, 1996.

[10]. **C.C.N. Uche and T.C. Joseph,** "Energy infrastructure in Nigeria and Achievement of Millennium Development Goals By 2015". Journal of Economic Studies Vol.6 Mar. 2007.

[11]. **A.F. Eugene, and G. Dora,** "Load Forecasting", State University of New York, pp. 269-285, New York, 2004.