ENERGY DEMAND FORECAST FOR THE INDUSTRIALIZATION OF NIGERIA USING TIME-SERIES ANALYSIS MODEL

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Abstracts. ***The growth of a country is largely dependent on the supply of adequate, affordable and reliable electric power. For Nigeria to be in tandem with other developed countries of the world which have exhibited a remarkable growth in economic development and become an industrialized nation, the existing gap between the electric power demand and supply of the country must be holistically bridged. The problems associated with poor, inadequate and unsupplied power to industries have been estimated in different ways by many studies. These studies evaluated various types of value of unproduced output and outage costs, such as equipment and material losses. It is a common knowledge in Nigeria that industries rely more on private (off-grid) power generation than the national grid. The diesel and petrol plants are commonly used generators and at times gas turbine plant, with the relative consequence of high cost of fueling. This alternative source of energy and technology has a direct negative impact on the cost of production as well as services. Within the ambient of socio-economic development and increase in human population, electric load demand is on the increase over the years. This research studies a load demand forecast for industrial areas of the power sector using-series as a tool for analysis. The results show that there is need to constantly improve its power generation, transmission and distribution network to deliver at least 20,000MW of power to its industries in other to meets the estimated or forecasted power of 19576.05 MW on or before the year 2030.***

Keywords: - Electricity Generation & Consumption, Energy Demand Modeling, Industrialization, Time Series Analysis and Energy Demand Forecast.

I. INTRODUCTION

It is very important to know that the forecast of power demand in Nigeria must be performed during and as an integral part of the power system design process. For it is not practical to add the load forecast at a later date for an attempt to do so could prove unrewarding and involves considerable and unnecessary cost even if it is physically possible [1]. Load forecasting is needed to reduce the transmission and distribution outages over the system and reduce system failure rate. The later section of this research focuses on the long term load forecasting of Nigeria electricity demand, and the method of forecasting employed is the stochastic/probabilistic extrapolation method which is based on the time-series analysis of past load demand curve using straight line graph/curve ($Y = a + bt$).

This research is imperative in order to predict/forecast the quantity of power needed by Nigerians 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 with special emphasis on the industrial area of the power sector. Energy is essential for all human activities and, indeed is critical to social and economic development.

Energy is only one of the many important inputs for production, conversion, processing, industrialization and commercialization in all sectors [2] [1]. It is generally recognized that energy, including electricity, plays a pivotal role in the economic development of any given country as it enhances the productivity of the nation when inputs such as capital and labor are considered.

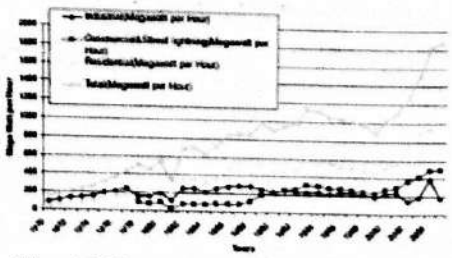
Access to electricity is crucial to human development. In practice, electricity is an indispensable commodity that is used for certain basic household activities, such as lighting, refrigeration and also for the running of household appliances. Hence, it cannot be easily replaced by other forms of energy [3]. There is difficulty in designing or evaluating policies and programs intended to address the impact of the use of energy within industrial areas/zones. The aim of this study is to be able to provide an appropriate analysis of how much power or energy do Nigeria need to efficiently, and affordably supply/feed its industries; thus what factors contribute to industrial energy demand. With the following key objectives:

To Investigate the dynamics of energy demand over time in Nigeria

To Identify the effects of the different factors on industrial energy demand

Also to Forecast the kilo-watt (KW) of energy Nigerians needed to supply its industries with utmost reliability that will in turn boost the annual gross-domestic product (GDP) of the country thereby making the economy grow at a very fast pace (and become an industrialized).

In 2004, the power sector reform bill was signed into law thus enabling private companies to take part in electricity generation, transmission, and distribution. By this reform act, the nation has a new map towards achieving a meaningful progress in her power sector. Figure 2 below shows the categories of electricity consumption figures between 1970 and 2004. It is also observed from the table below, that the percentage of electricity used for **Industrial** purposes has been on the decrease since 1970 while residential consumption has been on the increase [1]. This is easily explained by the epileptic and inadequate power supply that has forced many of the big industries to generate more of their own power and using less power from the national grid. Consequently, most of these companies where forced to fold up as they could no longer bear the burden of high cost of generating their electric power energy used for production.



1Figure 1.0: Electricity Generation in Nigeria, 1970-2005
Source: National Bureau of Statistics/Energy Commission of Nigeria

Figure 2.0: Electricity Consumption in Nigeria, 1970 to 2005
Source: National Bureau of Statistics/Energy Commission of Nigeria

II. AN OVERVIEW OF ELECTRICITY GENERATION AND DISTRIBUTION IN NIGERIA

The Nigerian economy is heavily dependent on energy. Electricity is used for a number of purposes that include industrial, commercial and residential purposes. Electricity generation in Nigeria began in 1896, fifteen years after its introduction in England. The law which established the national electric power authority (NEPA) in 1972 stipulates that (NEPA) develop and maintain an efficient, coordinated and cost effective electricity supply to all parts of Nigeira.

From the inception of NEPA in 1973, only five out of the then 19 state capitals were connected to the national transmission grid system. Today, practically all state of the federation is being served from the national grid, although haphazardly [1] On the other hand, in terms of distribution; TCN grid network has a total (theoretical) wheeling capacity of 7,500MW across over 20,000km transmission lines. The transmission system footprint does not cover every area of Nigeria [2]. A new generation and transmission peak of 5,375MW was achieved on Thursday 7th February 2019 at 2100hrs (TCN, 2019).

It is sad, that after six years of privatization, the electricity grid network is yet to be extended to reach many areas due to various challenges being face by the sector. Therefore, in other to proffer solution to the problem of epileptic power supply to Industrial areas in Nigeria and to increase the socio-economic development of the nation by carrying out proper planning towards determining the energy demand and supply forecast to industries in Nigeria is the motivation for this research paper.

A. Energy Demand Modeling

Energy estimation has been carried using so many methods, for instance Wassily [10] [7] uses input – output models to estimate. Also, The econometric modeling approach of energy demand, the Non-Stationary and the Co-Integration Technique [11] [12], Multivariate Co-Integration System (Johansen Approach) [13], and the Structural Time Series Model (STSM) [14] [15] [16].

A diversity of approach to the estimation of electricity demand can be found in the literature ranging from aggregative analysis of the relationship between electricity demand, income and prices [25], to more detailed disaggregated analysis [26]; based on simultaneous model structure. In the most basic model, the demand for electricity has been modeled as a function of a single variable, such as real income or temperature; real income and prices [27] real income, residential electricity price and price of natural gas [28]; real income, electricity prices, population growth, structural changes in the economy and efficiency improvement [29] population, income, price of electricity, price of oil, urbanization, weather; real income, price of electricity and diesel (used in for captive power generation to meet the shortages), and reliability of power supply from utilities real income, the real price of electricity, and the variable that captures the seasonal component of the demand for electricity.

Population is another important factor to determine electricity demand in Nigeria. Higher population level is expected to increase electricity consumption. A positive correlation between population growth and electricity demand is therefore expected. Economic theory suggests that electricity purchases will depend on the prices of substitutes: natural gas and petroleum products. However, the independent influences of diesel and gasoline prices may be rather small because a significant number of people in Nigeria do not have access to a power generating set to generate electricity when there is power outage. In our view, natural gas is not also appropriate in the case of Taiwan, since its consumption is concentrated on the urban rich and can be said to be comparatively small.

B. Industrialization Development in Nigeria and the Challenges

Power is needed to drive industrial machines for the manufacturing of different products; as a result, it contributes, significantly, to national economic growth. The power required to stimulate socio-economic activity in Nigeria, is grossly inadequate, consequently, there is high rate of unemployment, poverty, high cost of production and services, etc. However, there is an addition to this benchmark in the contemporary energy world, prompted by attributes of modern energy supply [3][4]. In the contemporary world, the consumption per capita of clean, adequate, affordable and sustainable power is a yardstick for measuring the quality of life and development of a country or region. Therefore, access to an efficient electric energy, is a panacea to the socio-economic development of a country.

Lack of power supply is a major reason why many industries has fold up in Nigeria today. Also making it difficult for new ones to thrive [11]. The reality is that manufacturing sector needs adequate, reliable and cost effective power supply to thrive and impact significantly on the commercial sector in Nigeria. From the global perspective, uninterrupted and safe energy supply is needed to fit into the fourth industrial revolution space that is characterized by full automation and digitization-based operations. Hence, for Nigeria to make significant growth economically, the development of the energy industries is a panacea. The negative impacts of inadequate electricity on the economies of Nigeria and other parts of SSA have been analyzed and reported by several studies [12-15]. The present situation negates the several huge interventions in terms of funds and policy framework initiatives by the government, and international community, therefore, a holistic developmental frame work in the power sector to increase her generation capacity so as to efficiently deliver to the industries for production.

C. The Effect of Inadequate Electricity on Industrial Sector in Nigeria

The effects of poor, inadequate and unsupplied power to manufacturing industries can never be over emphasized. This effect has been estimated in different ways by many researchers in different studies. These studies evaluated various types of value of unproduced output and outage costs, such as equipment and material losses [19, 20]. Ukong's study revealed that about 130 kWh and 172 kWh were the unsupplied electricity to selected manufacturing firms in 1965 and 1966 respectively [19]. These amounts correspond to N1.68 million and N2.75 million respectively, as the cost of power outage to the manufacturing sector in the two years. The study concluded that it had an adverse effect on manufacturing. A similar research was performed in 1993 in Lagos by Uchendu [20]. The study reported values of unproduced output for 1991, 1992 and mid 1993 were reported, as N1.3 million, N2.01 million and N2.32 million respectively. This development was reported to have caused reduction in economic value to major manufacturing firms in Lagos.

In 1992, it was reported that Nigeria's manufacturing sector spends approximately 90% of their variable cost on infrastructure [21] and power accounts for half of this-. To date, erratic, inadequate, poor and expensive power supply to manufacturing sectors and homes continuously dominant Nigeria's energy reports. Frequent power supply outage is detrimental to equipment and is a major cause of breakdown of production machinery. It is a common knowledge in Nigeria that industries rely more on private (off-grid) power generation than the national grid. The diesel and petrol plants are commonly used generators and at times gas turbine plant, with the relative consequence of high cost of fueling. Studies have shown that the source of energy and technology has a direct impact on cost of production and services.

The levelized cost approach, which is the preferred method, was applied in the analysis of cost of electricity generation in Nigeria between the different sources on the basis of equal footing [22]. The levelized cost of electricity (LCOE) described as the ratio of lifetime costs to lifetime electricity production.

III. METHODOLOGY

Having reviewed enough of literature in this work and many authors wrote and presented their finding, it is expected that this issue should have been laid to rest. But, because of technology advancement, efficient computation software, improved industrial revolution in automation, research in this area becomes endless. Therefore, the approach and methodology to this work will be time-series.

Time-series models are particularly useful when little is known about the underlying process one is trying to forecast. Also when properly applied, reveals more clearly the underlying trends especially in energy demand forecasting. In summary, a significant number of studies suggest that energy demand responds differently depending on whether prices fall, rise or above some previous maximum.

The research method used in analyzing the industrial energy demand forecast in Nigeria, is time series. In order to carry on with the analysis, they are fundamental knowledge or understanding we need in order to derive the model to a logical conclusion [1]

A. Time-Series Analysis

Time-series analysis is a widely used statistical method used in the task of seeing 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. The use of time-series in energy forecasting can never be over emphasized as it helps to predict or forecast the behavior of a variable in future also helps in the analysis of past behavior of a variable and helps in comparative studies in the value of different variables at different times or place [1]

Basically, load demand pattern in Nigeria can be categorized into three; the daily load demand, weekly load demand and the annual load demand. The daily load demand pattern in Nigeria is divided into off-peak and peak periods [28]. 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 occur 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 [1].

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 activities and as such so many home appliances are switched on [1].

Nigeria, weekly load demand follows 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. 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 [1].

Minimum annual load demand occurs between June and September, mid-November and early January with extreme wet period of the year and dry/hot period respectively when heaviest 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 [1].

The estimation of the trend of a time series starts with plotting the time series data on a graph. 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. For this paper, the least square method of the time series will be used in the analysis of our data.

B. 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. Since the most reliable method over the years in fitting trend line to a time series is the least square method, then it's become the best tool to generate the graph for our model.

The linear trend equation is given as; $Yt=a+bt$ ... (3.3)

Where; Yt = 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 Yt 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;

$at+b\sum t=\sum$ .....(3.4)

And

$a\sum t+b\sum t^2=\sum ty$ .....(3.5)

Where; t = 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;

$$a=\frac{\sum y}{n}-\frac{b\sum t}{n} \quad \text{.....(3.5)}$$

$$b\frac{n\sum ty-\sum t\sum y}{n\sum t^2-(\sum t)^2} \quad \text{.....(3.5)}$$

Where,

t = the time period

y = the value of the item measured against time

a = the Y-intercept and

b =the coefficient of t indicating slope of the trend.

IV. DATA SOURCE AND PRESENTATION

The data used in this research covers electrical energy consumption in Nigeria from 2000 – 2017 broken down into three categories, residential, commercial and industrial. They were collected from the National Bureau of Statistics and the Central Bank Statistical Bulletin. This table of values forms the basis for the estimation/forecasting of energy demand in Nigeria.

TABLE I
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
2013	1615.08	4424.78	8773.13	14812.99
2014	1617.73	4542.21	8933.23	15093.17
2015	1620.38	4659.64	9093.33	15373.35
2016	1620.03	4777.07	9253.43	15650.53
2017	1625.68	4894.50	9413.53	15933.71

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

From table 1.0 above, it shows the energy consumption rates in Nigeria from year 2000-2017. It comprises of five vertical sections and the first vertical section represents the number of years in view. The second, third, fourth and fifth vertical sections represent the industrial, commercial, and residential energy consumption data as well as the total. Since the raw data has been given we will substitute these values into our linear trend equation from equation (3) and then calculate statistically in a table. See table 2.0

Remember that our emphasis here is on industrial energy demand forecast.

From equation (3), Yt=a+bt

Where: $a = \frac{\Sigma y}{n} - \frac{b\Sigma t}{n}$ and $b \frac{n\Sigma ty - \Sigma t\Sigma y}{n\Sigma t^2 - (\Sigma t)^2}$

When t = 0 = gradient of the trend line

V. RESULTS AND DISCUSSION

The analysis of the industrial energy demand forecast is being presented using the table below.

A. Industrial Demand

TABLE II
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

The gradient of the trend line b=n ty−t yn t2−(t)2=2.65, a= yn−b tn=1596.53

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

The trend values and actual Industrial demand are shown in Table 3.0 below.

TABLE III
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

Note: The following key points.

1). Calculating the Accuracy of Industrial Forecast

The Mean Absolute Deviation *MAD = Actual − Forecast*

N=8.46 10−3*MW*

2). Predicted Industrial Demand

Using the trend line value of 2.65MW, we forecast for the future industrial load demand as shown in table 4.0 below:

TABLE IV
TABLE OF FORECAST VALUES FOR THE FUTURE INDUSTRIAL LOAD DEMAND

Year	Industrial Demand Forecast (MW)
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

B. 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 V
TOTAL PREDICTED LOAD DEMAND

Year	Predicted Load Demand(MW)
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

VI. SYSTEM IMPLEMENTATION

The simulated results for our analysis using the estimated values in the tables are shown in the following graphs below.

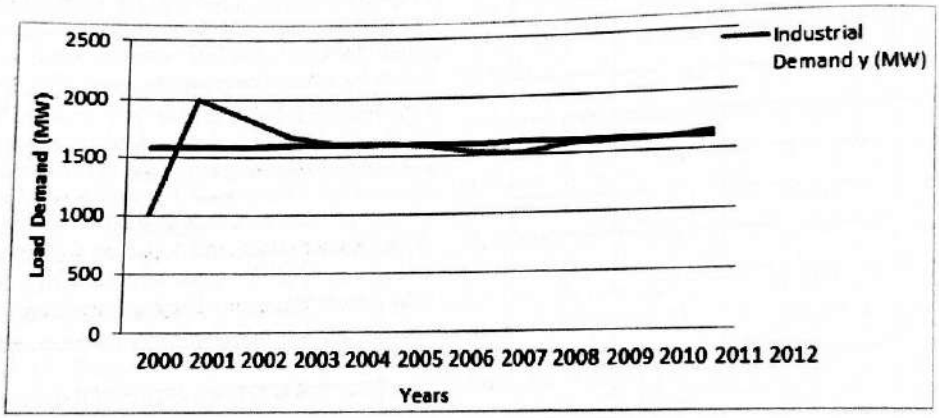


Figure 3.0: Graph of Nigeria Actual Industrial demand and trend values from 2000 – 2012

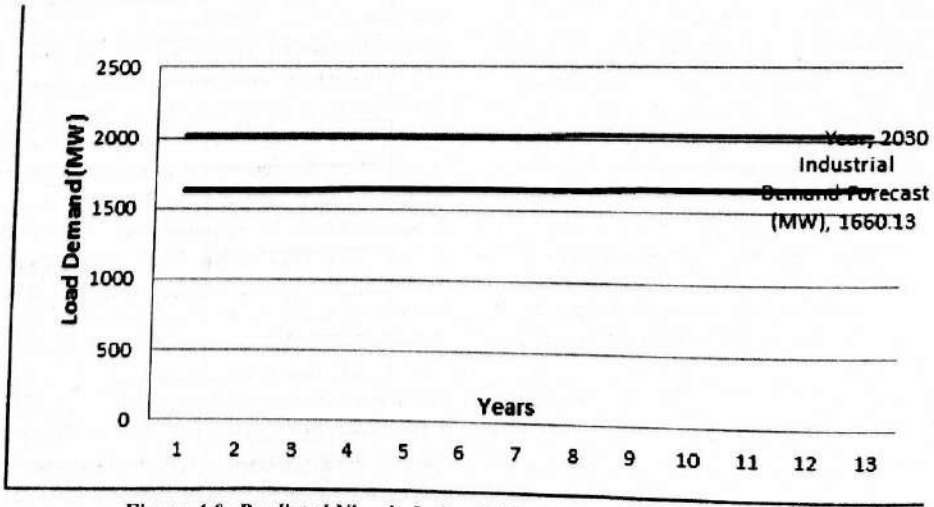


Figure 4.0: Predicted Nigeria Industrial load demand from 2018-2030

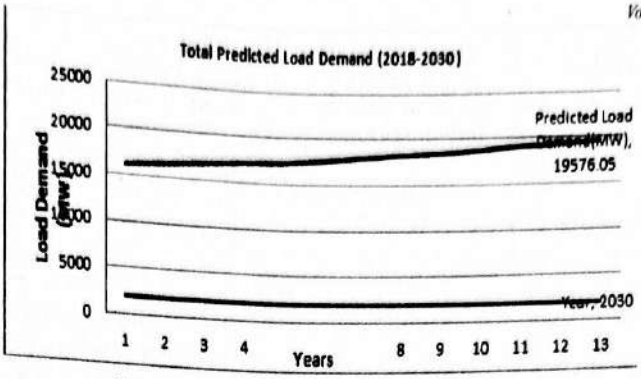


Figure 5.0: Nigeria Predicted Total load from 2018-2030

VII. CONCLUSION

Having investigated the Nigeria power sector and its performance over the years, it is observed with outmost disappointment that there is inadequate power supply due to insufficient power generation, transmission and obsolete distribution network that has cause the total collapse of the industrial sector of the economy. The results of this research work has shown that Nigeria need to build more power generation plants, invest in her transmission networks and rehabilitate all the existing distribution facilities in order to achieved the forecasted energy demand of 19,576.05MW. In view of the above, efficient, reliable and affordably electric power supply to her industrial areas can be achieved for this is the only way to industrialize the nation and improve the Gross Domestic Products (GDP) of her economy. The outcome of this project should guide the energy policy makers in Nigeria aimed at building more power plants and to increase more budgetary allocation to the power sector in order to achieve the estimated approximate 20, 000MW power by the year 2030.

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