Electrical Energy Demand Forecast in Nigeria Between 2020 - 2040 Using Probabilistic Extrapolation Method

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Abstract- Precise load forecasting is very vital for electrical energy utilities in a deregulated electricity market. Reliable and sufficient access to the electric power needed by several homes and businesses remain a great obstacles facing Nigeria. This paper focused on Nigeria electricity demand forecast from 2020 – 2040 using time series analysis on past load demand. The issue of Nigeria electricity supply challenges and possible solution or way forward for sufficient power has been discussed. Several load forecasting techniques, classification over the last few decades and review of previous work on this subject are also presented in this work. On the basics of these review the stochastic/probabilistic extrapolation method were employed. MATLAB was used for the computation and the results were analyzed and discussed. It was observed that there is a great positive link between the electricity demand and the years that as the year advances the demand for a reliable and affordable electrical energy supply increases. From the total predicted load demand, it is seen that Nigeria need over 17,000 MW in 2021 and over 23,000 MW in 2040 to be able to cater for the growing need of Nigerians. The average mean square error which determines the accuracy or precision of forecast was found to be approximately 0.52%. Load forecasting is needed to coordinate transmission and distribution outages over the network and reduce failure rate in the network. Load forecast are extremely important for energy suppliers, financial institutions and other users in electric energy generation, transmission, distribution and market.

Keywords Forecasting, Energy Demand, Probabilistic Extrapolation, MATLAB.

1. Introduction

The importance of energy availability, reliability and affordability in any nation in the economic growth, social and political development cannot be overemphasized. Energy plays a major role in the economic growth, progress and development of any nation. Available, reliable, efficient and affordable power supply is the hallmark of a developed economy. Any nation whose energy need is insufficient and inadequate in supply; prolong her development and risk of losing potential investors [1]. Electricity is the prime mover that drives the economic development of every country and any nation that does not pay attention or ignore its power sector is to at his peril. Energy is needed in any country for various purposes such as in residence to power domestic appliances and lightening purposes, commercial and institutional consumers for the provision of services and driving various devices and in the industries to drive various machines, equipment and purposes. The greatest engineering challenge in Nigeria today is the issue of the provision of adequate, reliable, efficient and affordable electricity supply to its consumers. Nigeria is facing a great issue of insufficient supply of electricity from the public utilities which has led to a situation where the nation is wallowing in darkness despite the vast energy resources. Thus the whole citizens of the country have been put into what was described as “Power

Cage" [2]. As a result of this only those individuals, establishment, institutions, industries and companies which are financially buoyant can liberate themselves from this cage by generating electricity to meet their needs. In Adesola [3] lecture on data capture processing, 2006 population and housing census of Nigeria in Tanzania, he reported that one of the key challenges/difficulties encountered in the 2006 census was lack of reliable and uninterrupted power. It was also reported in the Central Bank of Nigeria 4th quarter statistical bulletin (2012) that insufficient power supply is a major constraint to business growth and development in Nigeria with 69.3 index point as emphasized by the respondent firm. Business owners as a result of this deficiency generate their power to run their businesses which has now resulted to high cost of living.

According to the Vanguard Newspaper [4], the federal government of Nigeria under the administration of His Excellency Mohammed Buhari (GCFR) recorded an increase of 1,811.3 Megawatts in power generation, in January, 2019 as the transmission company of Nigeria (TCN) transmitted 127,157.7 Megawatts as against 125,346.4 Megawatts in December, 2018. However, this amount is insufficient to cater for the energy demand of a growing country like Nigeria. There is an extreme electricity deficiency in Nigeria which has result to a wide demand/supply gap. The unpalatable effect of this situation is felt by the masses.

Nigeria current population is estimated to be approximately 204 million as of Thursday, February 6, 2020 and she is ranked the 7th most populous country globally based on the United Nations estimate. By midyear of 2020 it is estimated to be approximately 206 million and by 2030, it is projected to rise to 252 million. Nigeria population is equivalent to 2.64% of the total whole population; the population density of Nigeria is 226 per km^2 with total land area of about 910,770km^2 which is equivalent to 351,650 Sq. miles [5]. Nigeria is projected to be the world's third most populous country by 2050, according to report release by the UN department of Economic and Social Affairs. Statistics by experts shows that by 2040, Nigeria population would have quadruple without proportionate employment and social amenities to sustain it.. Figure 1.1 and figure 1.2 shows the projected trend for Nigeria population. Nigeria has a low capacity utilization of 31% couple with high transmission and distribution losses of about 19%. Low capacity utilization is enhanced by technology used, age and condition of plant. Nigeria must therefore work towards improving capacity utilization by carrying out serious renovation on all the aged power plants and invest on modern and more efficient and reliable technology. Also Nigeria should make efforts for a well rounded energy mix, combining the enormous amount of available renewable energy with the non renewable fossil fuel. The gas being flared at the various crude oil refining station could be used to generate abundant electric power.

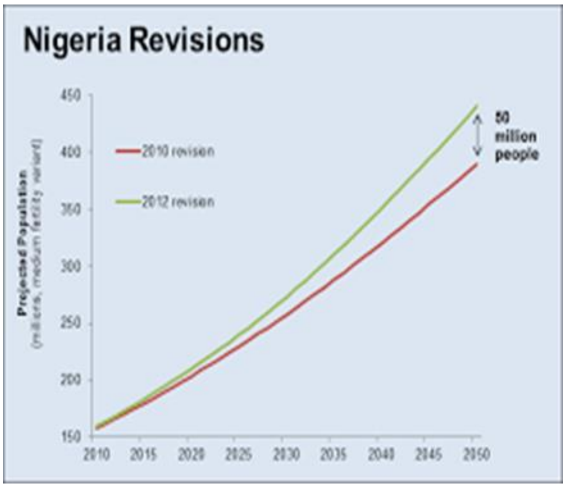

Fig. 1. Nigeria population 2050 estimation (Source: UN Population division) [6]

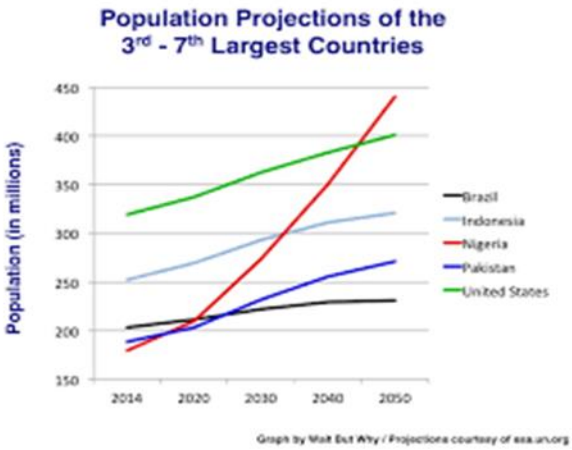

Fig. 2. Nigeria population 2050 estimation (Source: UN Population division) [6]

This blue print therefore covers and addresses the problems responsible for poor power generation, insufficient transmission facilities and poor distribution of transmitted power and also suggests an efficient, feasible and sustainable strategies for achieving reliable and affordable electric energy supply in Nigeria between 2020 – 2040

2. Nigeria Current Power Situation

2.1. Power Generation

Electricity was first generated in Lagos, Nigeria in the year 1896, fifteen (15) years after it was introduced in England. Although it was in 1929 that the first utility company, the Nigeria Electricity Supply Company (NESCO) was established. History also has it that it was in the 1950s and 1960s that the Nigerian government created the Electricity Corporation of Nigeria to control all coal/diesel fired isolated power plant across the country and the Niger Dam Authority to develop hydroelectric power in Nigeria. In 1972 these two entity were joined together to form the National Electric Power Authority (NEPA). In 2005 the "Reform Act" was established as a result of poor service quality of the National Electric Power Authority. With the passage of the Act, the assets and liabilities of the erstwhile NEPA was transferred to the Power Holding Company of Nigeria (PHCN). PHCN was subsequently unbundles into 18 companies, 6 generation company (GenCos), one transmission company (TCN/TransCo) and 11 distribution company (DisCos). The federal government retains the asset of the TransCo and privatize the GenCos and DisCos [7]. Through the efforts of the Independent Power Producers (IPP) and National Independent Power Projects (NIPP) generation has increased from the six (6) generating stations to twenty three (23); Afam (I-V), Afam VI (Shell), Egbin, Okpai, Kainji, Jebba, Sapele IPP, Sapele NIPP, Shiroro, Olorunsogo gas, Olorunsogo NIPP, Omotosho gas, Omotosho NIPP, Ughelli, Geregu gas, Geregu NIPP, Ihovbor NIPP, Ibom, Alaoji, Odukpani NIPP, A.E.S gas, Omoku and Transamadi, currently connected to the grid with a total install capacity of 11,165.4MW with available capacity of 7,139.6MW. 81% of these generation is thermal based, with an installed capacity of 9,044MW and available capacity of 6,079.6MW. Hydropower also account for about 1,938.4MW of total installed capacity with available capacity of 1,060MW [8]. Table 1 shows the six (6) successor GenCos in Nigeria with their location, plant type and available installed capacities.

Table 1. Nigeria 6 Successor GenCos Showing Their Location, Plant type and Available Generating Capacities

S/N	GENCOS	LOCATION	PLANT TYPE	CAPACITY (MW)
1	Afam Power Plc (I-V)	Rivers	Thermal	987.2
2	Egbin Power Plc	Lagos	Thermal	1,320
3	Kainji/Jebba Hydro Electric Plc	Niger	Hydro	1,330
4	Sapele Power Plc	Delta	Thermal	1,020
5	Shiroro Hydro Electric Plc	Niger	Hydro	600
6	Ughelli Power Plc	Delta	Thermal	942

2.2. Power Transmission

Primary transmission of electricity in Nigeria is facilitated by 330kv and 132kv lines with 33kv as sub-transmission. According to [9] approximately 40% of the country populations have access to electricity. The larger part of this population lives in the rural area where there are no infrastructures for electricity supplies with just around 36% access to power. Even these percentages that are connected to the national grid have electricity deficiency. Presently, there is an 80 percent demand/supply gap for electricity in Nigeria. Most business, industries, organization e.t.c generate electricity on their own to meet their need. Nigeria transmission network is presently overloaded with a poor voltage profile in most part of the network. There are frequent collapses on the network, these has led to a high transmission losses. Report from Nation Newspaper [10], there was a serious collapses on the Nigeria transmission line which was attributed to too much switching on the lines and generator failure. The network coverage is inadequate, resulting primarily from the economics of power transmission, government interference, overbearing, hostile communities and vandalization. The network also suffers lack of modern asset management and operational processes, outdated systems, inability to implement, super grid concepts and huge debt burden from administration to administration arising from power generation and distribution companies not receiving appropriate payment for their services.

2.3. Power Distribution

Electricity distribution companies in Nigeria (DisCos) are currently 11 for power distribution to residential, commercial and industrial users. When the electricity reaches the distribution companies (DisCos), they make use of distribution transformers to step down the voltage (33kv) from the sub-transmission station to 11kv and from 11kv to 415v, in some cases 33kv to 415v directly. Table 2 gives a list of the eleven (11) distribution companies in Nigeria and their areas of operation.

However, the power distribution network in Nigeria are overloaded, old and weak hence Nigerians suffers low voltage supply most of the time, unreliable and insufficient transformers resulting in frequent power outage. Also the network suffers from general poor sector management from the absence of Independent System Operators (ISO) which is the practice of countries with deregulated system. More so, there are frequent collapses of poles which may arise from human error or changes in whether condition resulting to black out in affected areas for a long period of time.

Table 2. Nigeria 6 Successor GenCos Showing Their Location, Plant type and Available Generating Capacities

S/N	DISCOS	AREAS OF OPERATION
1.	Abuja Distribution Company	Abuja, Kogi, Niger
2.	Benin Distribution Company	Edo, Delta, Ekiti, Ondo
3.	Eko Distribution Company	Lagos (Island, Victoria Island, Lekki to Epe)
4.	Enugu Distribution Company	Abia, Anambra, Ebonyi, Enugu and Imo
5.	Ibadan Distribution Company	Kwara, Ogun, Osun and Oyo
6.	Ikeja Distribution Company	Lagos (All of mainland, Ikeja to Badagry)
7.	Jos Distribution Company	Bauchi, Benue, Gombe, Nassarawa, Pleteau
8.	Kaduna Distribution Company	Kaduna, Kebbi, Sokoto, and Zamfara
9.	Kano Distribution Company	Jigawa, Kano and Kastina
10.	Port Harcourt Distribution Company	Akwa Ibom, Bayelsa, Cross River and Rivers
11.	Yola Distribution Company	Yobe , Taraba , Adamawa and Borno,

Source: Federal Ministry of Power [11]

2.4. Classification and Forecasting Techniques Submission Process

Based on diverse studies and research the load forecasting techniques/methods may be broadly grouped into three main groups; traditional forecasting techniques, modified traditional techniques and soft computing techniques [12].

2.4.1. Traditional Forecasting Techniques

Traditional forecasting techniques were the methods used in the early days by researchers in planning and predicting future load demand, infrastructure, development trends and the overall development index of the country. These forecast or predictions were usually carried out by traditional/conventional mathematical techniques. With findings of researchers and the introduction of advanced methods these techniques have been improved for better forecasting in diverse fields of study both in social science, science and engineering. The traditional/conventional forecasting or predictions techniques used in early days are; exponential smoothing, regression, multiple regression, and iterative reweighted least-square techniques [13 – 16].

2.4.2. Modified Traditional Techniques

The traditional/conventional forecasting techniques were developed in such a way that under varying environmental conditions they automatically correct the parameters of forecasting models. Some of the modified techniques or versions of the traditional techniques are; adaptive demand forecasting method, support vector machine based techniques and stochastic time series approach [17 – 20].

2.4.3. Soft Computing Techniques

A computer based approach called soft computing technique has emerged in research to deal with models effectively. It has been used over the last few years as a result of its simplicity and flexibility. The basic benefit of soft computing approach is its precision, certainty and intelligent to exploit whenever possible. It is emerging fast as an approach to help computer based intelligent systems mimic the intelligent quotient of the human brain to employ mode of reasoning that are approximate rather than accurate. Soft computing encompasses various areas such as neural networks (NNs), fuzzy logic (FL), evolutionary algorithms (EAs) i.e genetic algorithms (GAs) e.t.c. Artificial intelligence (AI) are as a result of biological evolution over millions of years. Evolution today has stimulate living systems towards higher-level of intelligence. The GA is one of the relatively simple and newer optimization approaches which are based on the evolutionary principle of natural selection. One of its advantage and quality is that it is a free optimization approach with no derivation.. [21 – 23].

2.5. Time Series Analysis

Time series analyses are statistical techniques used in analyzing past data and projecting these data to obtain future values. Time series analysis can also be defined as sets of observations recorded over a period. It is a commonly used statistical approach in projecting into the future. There are several types of time series analysis, these are economic time series, demographic time series, marketing time series and physical time series analysis

2.6. Estimation of Trend

The trend estimation of a time series starts with plotting a time series graph based on available data. The scatter diagram obtained from the plot give the idea of the appropriate trend line to fit the data. If the points from the plot are closely related, a straight line trend will be fitted in the data. The trend line can be obtained by using one of the followings approach; (i) the free hand method (ii) the method of moving average (iii) the least square method.

The linear equation obtained from the equation of a straight line used in fitting trend line to a time series is given as:

$$Y_t = a + bt \quad (1)$$

Where,

Y_t = The trend value for a given time (t)

a = The trend line value when t = zero (0)

b = The slope or gradient of the trend line

t = The time limit. The parameters of the trend equation that determine the estimates are "a" and "b". They are obtained by solving the followings normal statistical equations:

$$na + b\Sigma t = \Sigma y \quad (2)$$

$$a\Sigma t + b\Sigma t^2 = \Sigma ty \quad (3)$$

Where n = number of years under study. We can also obtain this from the value of "a" and "b" by minimizing the sum of squares of errors. The parameters estimate can be calculated by using the formula:

$$a = \frac{\Sigma y}{n} - \frac{b\Sigma t}{n} \quad (4)$$

$$b = \frac{n\Sigma ty - \Sigma t\Sigma y}{n\Sigma t^2 - (\Sigma t)^2} \quad (5)$$

2.7. Measuring Accuracy of Forecast

The accuracy of prediction or forecast can be obtained by measuring the mean absolute deviation (MAD) or the sum of square of errors.

$$MAD = \frac{\Sigma(Actual - Forecast)}{n} \quad (6)$$

$$SSE = \Sigma(Actual - Forecast)^2 \quad (7)$$

It is important to note that the value of SSE or MAD determine the accuracy of forecast [24].

3. Methodology

3.1. Research Design

This work adopts “The stochastic/probabilistic extrapolation method” to achieve the optimized result. This method is one of the modified traditional forecasting techniques. It is based on the time series analysis of the load demand curve by means of regression models. The projected load demand are obtained by extrapolating the resulting trend line (curve) using the trend value. The block diagram of the research is as shown:

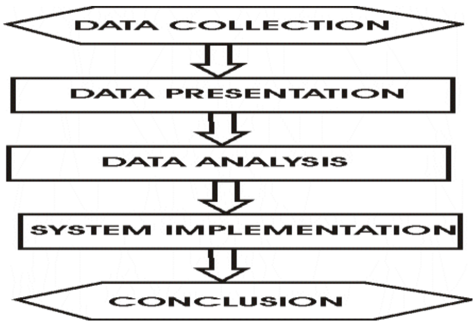

Fig. 3. Block diagram of the research design.

3.2. Data Source and Presentation

The data used in this work are obtained from the National Bureau of Statistics and the Central Bank of Nigeria Statistical Bulletin. It comprises of electrical energy consumption in Nigeria from 2008 – 2018 broken down into three categories, residential, commercial and industrial.

Table 3: Energy Consumption in Megawatt (MW)

Year	Residential	Commercial	Industrial	Total
2008	7910.08	3852.00	1502.50	13264.55
2009	8075.00	3865.50	1585.00	13525.50
2010	8205.20	3925.80	1589.40	13720.40
2011	8285.60	4004.70	1615.50	13905.80
2012	8350.00	4025.40	1648.00	14023.40
2013	8773.13	4424.78	1615.08	14812.99
2014	8933.23	4542.21	1617.73	15093.17
2015	9093.33	4659.64	1620.38	15373.35
2016	9253.43	4777.07	1623.03	15653.53
2017	9413.53	4894.50	1625.68	15933.71
2018	9573.63	5011.93	1628.33	16213.89

Source: (Central Bank of Nigeria Statistical Bulletin, National Bureau of Statistics (NBS) and Dikio et al) [25 -26]

3.3. Data Analysis

3.3.1. Residential Demand Forecast

The residential demand forecast is calculated below using the data in Table 4.

Table 4: Table of residential demand forecast.

Year	T	Residential Demand y (MW)	ty	t^2
2008	-5	7910.08	-39550.40	25
2009	-4	8075.00	-32300.00	16
2010	-3	8205.20	-24615.60	9
2011	-2	8285.60	-16571.20	4
2012	-1	8350.00	-8350.00	1
2013	0	8773.13	0.00	0
2014	1	8933.23	8933.23	1
2015	2	9093.33	18186.66	4
2016	3	9253.43	27760.29	9
2017	4	9413.53	37654.12	16
2018	5	9573.63	47868.15	25
Total	**0**	**95866.16**	**19015.25**	**110**

From equation (1)

$Y = a + bt$

Where $a = \frac{\Sigma y}{n} - \frac{b\Sigma t}{n}$ = Trend line value when t=0

And $b = \frac{n\Sigma ty - \Sigma t \Sigma y}{n\Sigma t^2 - (\Sigma t)^2}$ = Gradient of the trend line

Substituting the value of a and b into equation 1, we shall have;

$$a = \frac{95866.16}{11} = 8715.10$$

$$b = \frac{11(19015.25) - 0(95866.16)}{11(110) - (0)^2} = \frac{11(19015.25)}{11(110)} = 172.86$$

Therefore, $Y = 8715.10 + 172.86t$. The trend values are given below:

Table 5: Trend values.

Year	Residential Demand y (MW)	Trend value Y (MW)
2008	7910.08	7850.80
2009	8075.00	8023.66
2010	8205.20	8196.52
2011	8285.60	8369.38
2012	8350.00	8542.24
2013	8773.13	8715.10
2014	8933.23	8887.96
2015	9093.33	9060.32
2016	9253.43	9233.68
2017	9413.53	9406.54
2018	9573.63	9579.40
Total	**95866.16**	**95866.10**

Solving for the accuracy of residential forecast,

$$MAD = \frac{\Sigma(Actual - Forecast)}{n} \qquad (7)$$

$$MAD = \frac{95866.16 - 95866.10}{11} = \frac{0.06}{11} = 5.54 \times 10^{-3} MW$$

Table 6: Table of commercial demand forecast.

Year	t	Commercial Demand y (MW)	ty	t^2
2008	-5	3852.00	-19260.00	25
2009	-4	3865.50	-15462.00	16
2010	-3	3925.80	-11777.40	9
2011	-2	4004.70	-8009.40	4
2012	-1	4025.40	-4025.40	1
2013	0	4424.78	0.00	0
2014	1	4542.21	4542.21	1
2015	2	4659.64	9319.28	4
2016	3	4777.07	14331.21	9
2017	4	4894.50	19578.00	16
2018	5	5011.93	25059.65	25
Total	**0**	**47983.53**	**14296.15**	**110**

3.3.2. Commercial Demand Forecast

The table of values for commercial demand forecast is given below:

From equation (1)

$Y = a + bt$

Where $a = \frac{\Sigma y}{n} - \frac{b\Sigma t}{n}$ = Trend line value when t=0

And $b = \frac{n\Sigma ty - \Sigma t\Sigma y}{n\Sigma t^2 - (\Sigma t)^2}$ = Gradient of the trend line

Substituting the value of a and b into equation 1, we shall have;

$$a = \frac{47983.53}{11} = 4362.13$$

$$b = \frac{11(14296.15) - 0(47983.53)}{11(110) - (0)^2} = \frac{11(14296.15)}{11(110)} = 129.96$$

Therefore, $Y = 4362.13 + 129.96t$. The trend values are given below:

Table 7: Trend values.

Year	Commercial Demand y (MW)	Trend value Y (MW)
2008	3852.00	3712.33
2009	3865.50	3842.29
2010	3925.80	3972.25
2011	4004.70	4102.21
2012	4025.40	4232.17
2013	4424.78	4362.13
2014	4542.21	4492.09
2015	4659.64	4622.05
2016	4777.07	4752.01
2017	4894.50	4881.97
2018	5011.93	5011.93
Total	**47983.53**	**47983.43**

Solving for the accuracy of commercial forecast

$$MAD = \frac{\Sigma(Actual - Forecast)}{n}$$

$$MAD = \frac{47983.53 - 47983.43}{11} = \frac{0.1}{11} = 9.09 \times 10^{-3} MW$$

3.3.3. Industrial Demand Forecast

The table of values for industrial demand forecast is given below;

Table 8: Trend values.

Year	t	Industrial Demand y (MW)	ty	t^2
2008	-5	1502.50	-7512.50	25
2009	-4	1585.00	-6340.00	16
2010	-3	1589.40	-4768.20	9
2011	-2	1615.50	-3231.00	4
2012	-1	1648.00	-1648.00	1
2013	0	1615.08	0.00	0
2014	1	1617.73	1617.73	1
2015	2	1620.38	3240.76	4
2016	3	1623.03	4869.09	9
2017	4	1625.68	6502.72	16
2018	5	1628.33	8141.65	25
Total	**0**	**17670.63**	**872.25**	**110**

From equation (1)

$Y = a + bt$

Where $a = \frac{\Sigma y}{n} - \frac{b\Sigma t}{n}$ = Trend line value when t=0

And $b = \frac{n\Sigma ty - \Sigma t\Sigma y}{n\Sigma t^2 - (\Sigma t)^2}$ = Gradient of the trend line

Substituting the value of a and b into equation 1, we shall have;

$$a = \frac{17670.63}{11} = 1606.42$$

$$b = \frac{11(872.25) - 0(17670.63)}{11(110) - (0)^2} = \frac{11(872.25)}{11(110)} = 7.92$$

Therefore, $Y = 1606.42 + 7.92t$. The trend values are given below:

Table 9: Trend values.

Year	**Industrial Demand y (MW)**	**Trend value Y (MW)**
2008	1502.50	1566.82
2009	1585.00	1574.74
2010	1589.40	1582.66
2011	1615.50	1590.58
2012	1648.00	1598.50
2013	1615.08	1606.42
2014	1617.73	1614.34
2015	1620.38	1622.26
2016	1623.03	1630.18
2017	1625.68	1638.10
2018	1628.33	1646.02
Total	**17670.63**	**17670.62**

Solving for the accuracy of commercial forecast

$$MAD = \frac{\Sigma(Actual - Forecast)}{n}$$

$$MAD = \frac{17670.63 - 17670.62}{11} = \frac{0.01}{11} = 9.09 \times 10^{-4} MW$$

Calculating the average mean absolute deviation (AMAD)

$$AMAD = \frac{MAD\ of\ Residential + MAD\ of\ Commercial + MAD\ of\ Industrial}{3}$$

$$AMAD = \frac{0.00554 + 0.00909 + 0.000909}{3} = \frac{0.015539}{3} = 0.005179$$

This is approximately 0.52%

4. Results and Discussions

4.1. Predicted Residential Demand

The predicted residential demand is obtained by either summing the trend line value (172.86MW) to the preceding load demand to obtain the current years forecast demand up to 2040 or by simply substituting into the trend equation to obtained Table 10.

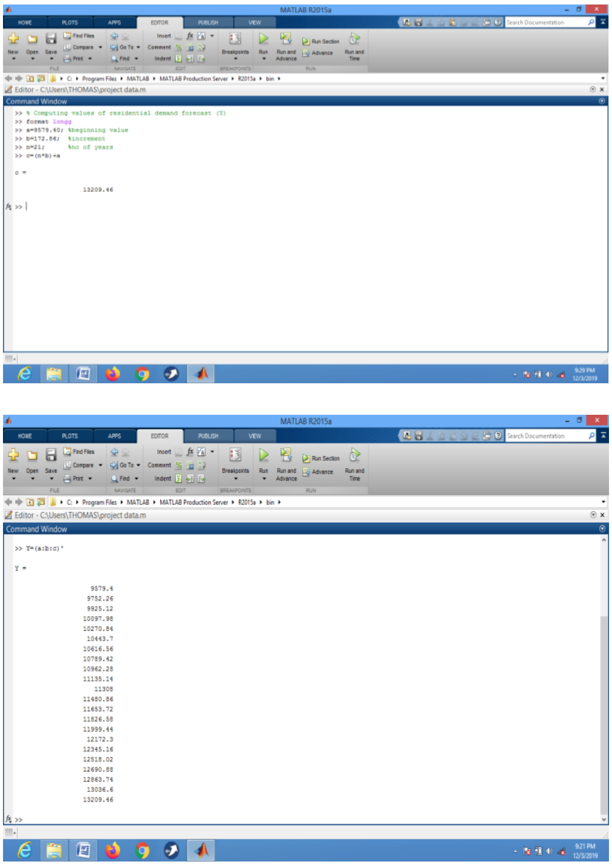

Fig. 4. Computed residential demand forecast.

Table 10: Table of predicted residential demand value.

Year	Residential Demand Forecasted Y (MW)
2019	9752.26
2020	9925.12
2021	10097.98
2022	10270.84
2023	10443.70
2024	10616.56
2025	10789.42
2026	10962.28
2027	11135.14
2028	11308.00
2029	11480.86
2030	11653.72
2031	11826.58
2032	11999.44
2033	12172.30
2034	12345.16
2035	12518.02
2036	12690.88
2037	12863.74
2038	13036.60
2039	13209.46
2040	13382.32

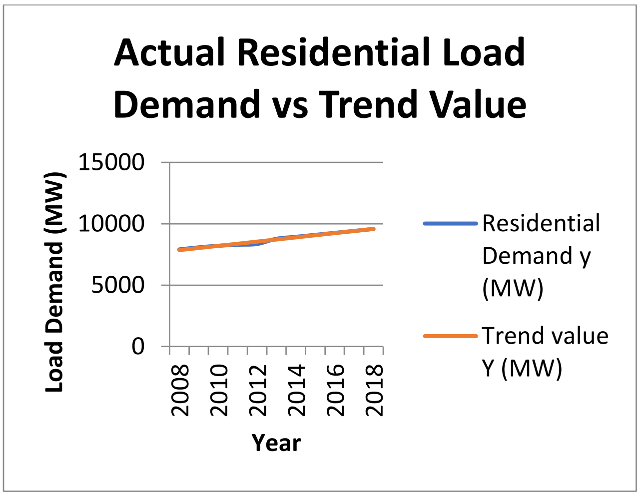

Fig. 5. Graph of actual residential load demand and trend values from 2008 – 2018.

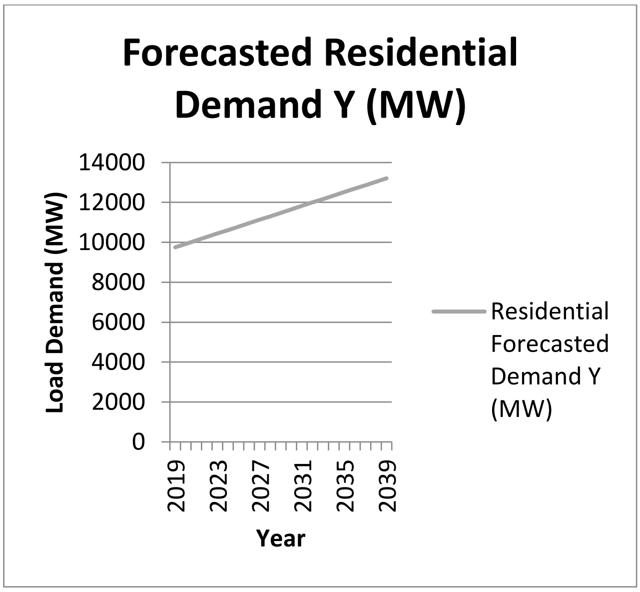

Fig. 6. Graph of Nigeria predicted residential load demand 2020 – 2040.

4.2. Predicted Commercial Demand

The predicted commercial demand is obtained by either summing the trend line value (129.96MW) to the preceding load demand to get the current years forecast demand up to 2040 or by using the trend equation to obtained Table 11.

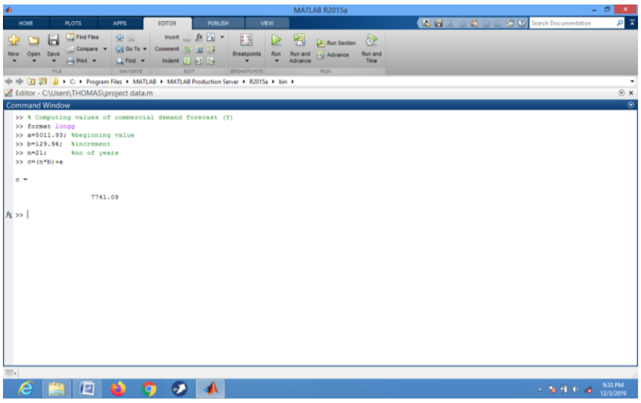

Fig. 7. Computed commercial demand forecast

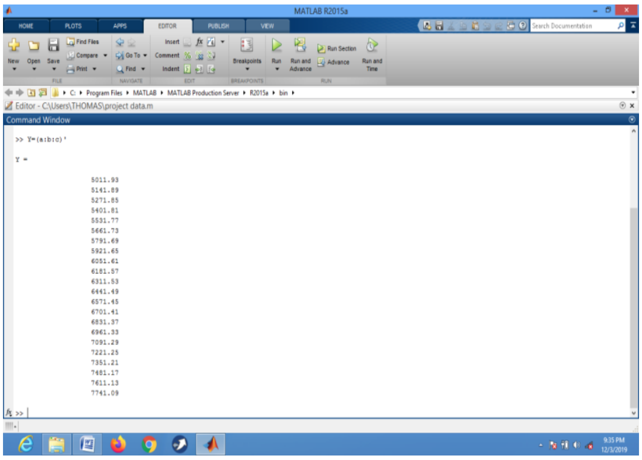

Fig. 7. Contd.

Table 11: Table of predicted commerical demand value.

Year	**Commercial Demand Forecasted Y (MW)**
2019	5141.89
2020	5271.85
2021	5401.81
2022	5531.77
2023	5661.73
2024	5791.69
2025	5921.65
2026	6051.61
2027	6181.57
2028	6311.53
2029	6441.49
2030	6571.45
2031	6701.41
2032	6831.37
2033	6961.33
2034	7091.29
2035	7221.25
2036	7351.21
2037	7481.17
2038	7611.13
2039	7741.09
2040	7871.05

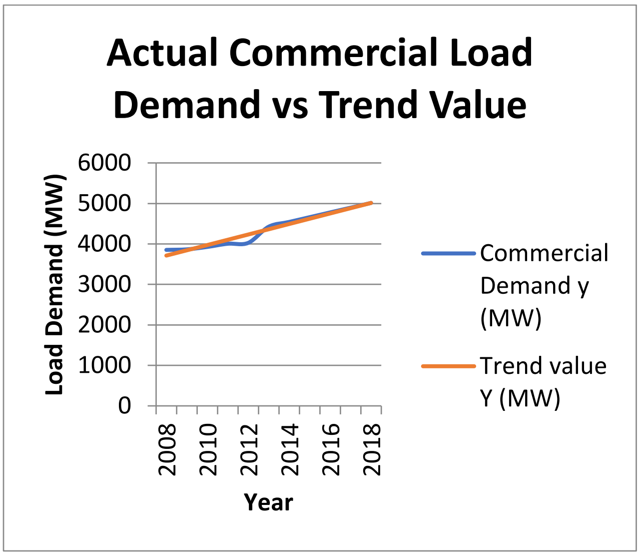

Fig. 8. Graph of actual commercial load demand and trend values from 2008 – 2018.

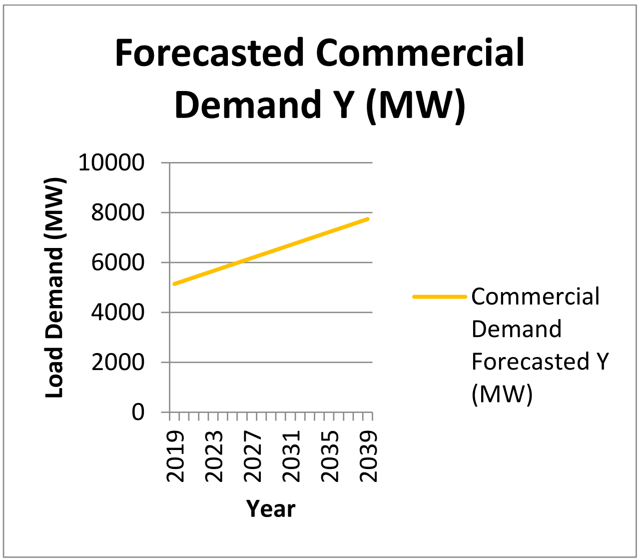

Fig. 9. Graph of Nigeria predicted commerical load demand 2020 – 2040.

4.3. Predicted Industrial Demand

The predicted industrial demand is obtained by either summing the trend line value (7.92MW) to the preceding load demand to get the current years forecast demand up to 2040 or by using the trend equation to obtained Table 12.

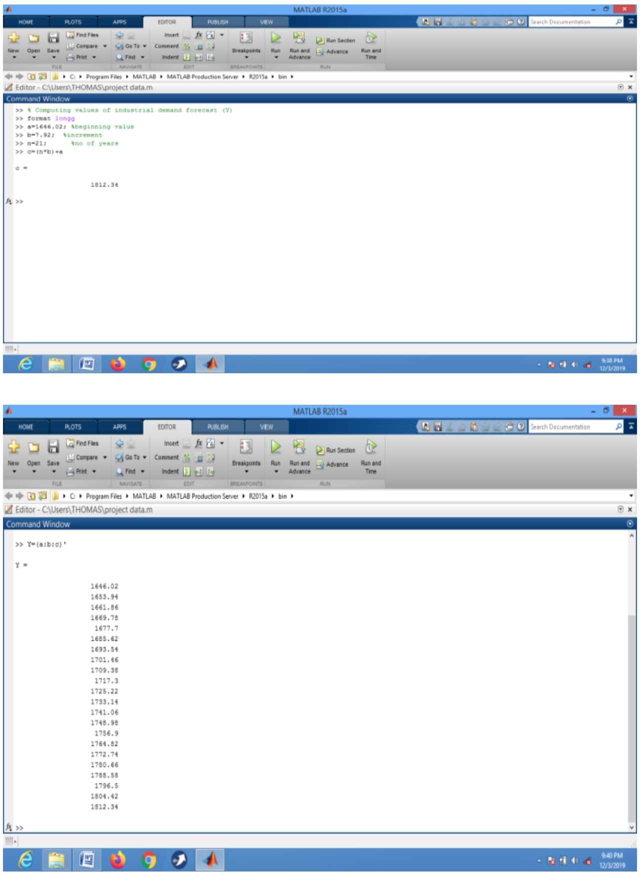

Fig. 10. Computed industrial demand forecast

Table 12: Table of predicted industrial demand value.

Year	Industrial Demand Forecasted Y (MW)
2019	1653.94
2020	1661.86
2021	1669.78
2022	1677.70
2023	1685.62
2024	1693.54
2025	1701.46
2026	1709.38
2027	1717.30
2028	1725.22
2029	1733.14
2030	1741.06

2031	1748.98
2032	1756.90
2033	1764.82
2034	1772.74
2035	1780.66
2036	1788.58
2037	1796.50
2038	1804.42
2039	1812.34
2040	1820.26

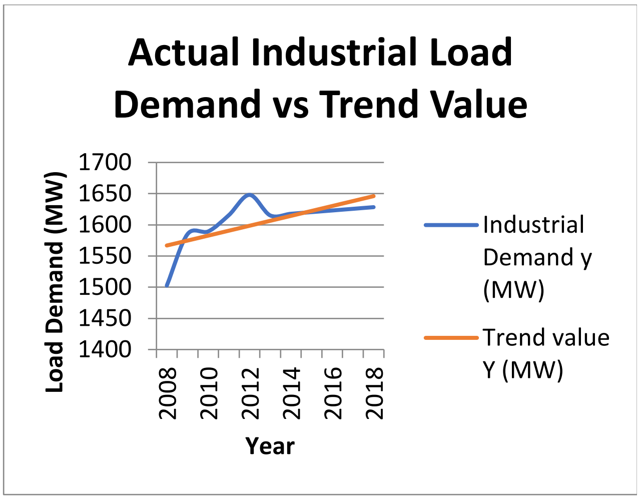

Fig. 11. Graph of actual industrial load demand and trend values from 2008 – 2018.

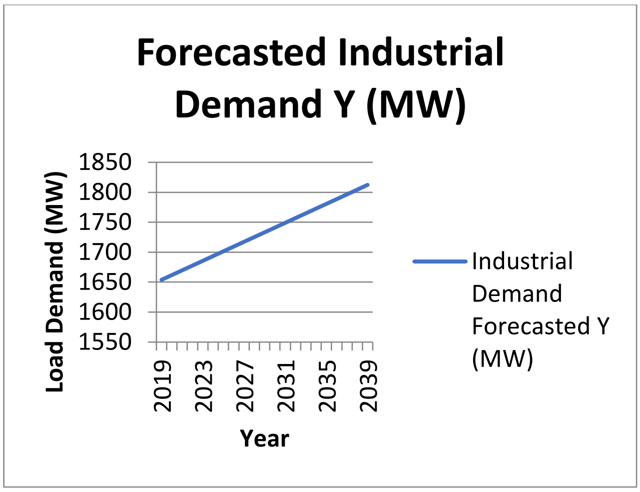

Fig. 12. Graph of Nigeria predicted industrial load demand 2020 – 2040.

4.4. Total Predicted Load Demand

The overall, predicted load demand is obtained by summing the individual demand forecasted; residential, commercial and industrial to obtain Table 13

Table 13: Total predicted load demand

Year	**Total Predicted Load Demand (MW)**
2019	16548.08
2020	16858.83
2021	17169.57
2022	17480.31
2023	17791.05
2024	18101.79
2025	18412.53
2026	18723.27
2027	19034.01
2028	19344.75
2029	19655.49
2030	19966.23
2031	20276.97
2032	20587.71
2033	20898.45
2034	21209.19
2035	21519.93

2036	21830.67
2037	22141.41
2038	22452.15
2039	22762.89
2040	23073.63

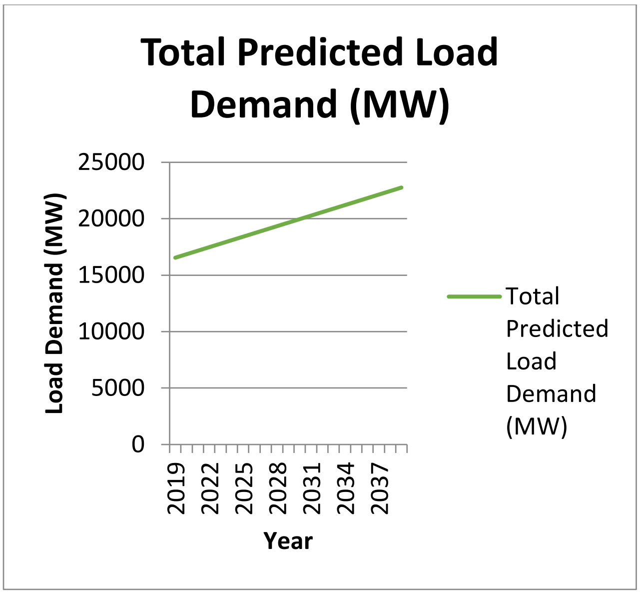

Fig. 13. Graph of Nigeria total predicted load demand 2020 – 2040.

5. Conclusion

Electricity is the prime mover that propels the socio-economic development of every country and any Nation that does not pay attention or ignore its power sector is to at his peril. Electricity supply in Nigeria is grossly inadequate. Demand is more than total installed capacity and the available capacity is barely above half of the installed capacity. This has resulted to a large demand - supply gap. From the total predicted load demand, it is seen that Nigeria need over 17,000 MW in 2021 and over 23,000 MW in 2040 to be able to cater for the growing need of Nigerians. The average mean square error which determines the accuracy or precision of forecast was found to be approximately 0.52% which is small compared to other approaches.

It was also observed that there is a great positive link between the electricity demand and the years that as the year moves forward the demand for electricity also rises. MATLAB (R2015b) was used for the simulation.

The knowledge obtained from this work will help the Nigeria Government to restructure the abnormalities in her power sector, make important decision on load switching, contract evaluation, network reconfiguration, voltage control and infrastructure development. In engineering planning and design, it will help the utility engineer to know the amount of energy an area will need at a particular time. It will also help the engineer in the scheduling of the downstream networks. In finance planning accurate demand forecast will help the finance team to know the sizes of generator to install or purchase at a given time, cabling and metering and all cost functions.

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