LOAD DEMAND FORECAST FOR CAPACITY ALLOCATION AND GENERATION EXPANSION PLANNING USING REGRESSION ANALYSIS

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ABSTRACT: This paper predicts the electrical load demand forecast in Nigeria by the year 2032. The data used in this work cover electrical energy consumption in Nigeria from (2000-2012) broken down into three categories: residential, commercial and industrial. The data are collected from the national Bureau of statistics and the central Bank of Nigeria, Statistical Bulletin, for analysis. Least-square regression techniques were used for the analysis and investigation. The analyzed results were used for the prediction of the lord energy demand forecast in Nigeria in year 2032, which evidently give a totaling of residential, commercial and industrial load demand of 20136.41MW. The energy dem and forecast is an essential activity of electric power providers, without an "accurate" picture of the future, which may be based upon in the pass-history, over-capacity or (under-capacity) in the power system may seriously result to unexpected cost. The load forecast result, obtained served as the input data for "capacity –allocation" and generation expansion planning.

Keywords: capacity allocation, commercial load, energy consumption, industrial load, load forecast, regression analysis, residential load

1. Introduction

The electrical utilities, regulatory agencies have been mandated by law to generate electricity, transmit and distribute at different voltage level to the load centre at the receiving ends [1]. The power station feed different types of consumer: Domestic, commercial, industrial, agricultural etc. The present day power stations invariably feed a grid power system, which delivers power to the load centers. The design of power plant or system must take into account the future increase in load. For this reason load forecasting studies have to be made to predict the increase in load in the next 20years. The estimate of electric power and the increase in generation capacity depends: on maximum demand, distribution and variation in demand and energy requirements. Because the purpose of electrical power system is to supply load to the respective end-users , with the aim of satisfying the equality-constraints condition[2]. Therefore conscious attempt is seriously needed to alleviate the problems confronting any electric supply utilities to undertake the peak-power demand at all time[3]. The techniques rely on the analysis of least –square regression analysis, considering the historical and the present day civilization of mankind are closely interwoven with energy, and there is no reason to doubt but that in the future our existences will be more and more dependent upon the energy. The electrical energy occupies the top position in the energy hierarchy and therefore, it find innumerable uses in home, industry, agriculture, commercial and even in transport sector[4]. Consequently, the rapid increase in population of people migrating from the rural areas to the urban cities had led to an unprecedented growth in the energy demand, which in strong terms not matching the generating capacity, resulting to over load problems. Due to the increasing dependence on so many infrastructural sectors, on daily basis in a way to make comfort for man and humanity thereby engaging continuity of electric supply from the electricity utilities system particularly, Nigeria should be given a strong concern . Therefore there is need and necessity for electric load demand forecast which, ideally assumed a great importance[5].

2. Data presentation: Load forecast result:

The data used in this work cover electrical energy consumption in Nigeria from (2000-2012) broken

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down into three categories: residential, commercial and industrial. They are collected from the National Bureau of statistics and the Central Bank of Nigeria, Statistical Bulletin.

3. Data Input

Table 1: Table of Energy Consumption (MW)

ENERGY CONSUMPTION				
YEAR	**RESIDENTIAL**	**COMMERCIAL**	**INDUSTRIAL**	**TOTAL**
2000	4608.40	2346.00	1011.60	8688.90
2001	7714.80	2439.00	1987.20	9034.40
2002	7668.50	3297.60	1830.00	12842.40
2003	7668.50	3583.00	1659.80	12866.60
2004	7725.30	3830.30	1605.00	13160.60
2005	7760.00	3851.00	1615.50	13226.60
2006	7650.00	3900.80	1575.00	13125.80
2007	7860.30	3915.00	1530.50	13305.80
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

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

The data collected served as the input for the generation expansion planning (decomposition techniques): includes totaling the residential, commercial and industrial load demand which gives **20,136.41MW.**

4. Data Analysis: Residential Forecast

The residential demand forecast is performed using the data below: computation of residential load demand using regression analysis techniques.

Table 2: Table of Residential Demand Forecast

YEAR	X	RESIDENTIAL DEMAND (MW)Y	XY	X²
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	7910.08	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**

CASE 1: RESIDENTIAL DEMAND

From our straight line (trend line) given by:

From $Y = a + bx$ (1)

Where; $a = \frac{\Sigma y}{n} - \frac{b\Sigma x}{n}$ = trend line value, (2)

$$b = \frac{n\Sigma xy - \Sigma x\Sigma y}{n\Sigma x^2 - (\Sigma x)^2} \quad (3)$$

Substituting the data into equation (1,2 & 3) we have:

$$\Sigma xy = 29139.76$$
$$\Sigma x = 0$$
$$\Sigma y = 99481.68$$
$$\Sigma x^2 = 182$$
$$n = 13$$

$$b = \frac{n\Sigma xy - \Sigma x\Sigma y}{n\Sigma x^2 - (\Sigma x)^2} = \frac{13 \times 29139.76 - 0 \times 99481.68}{13 \times 182 - 0^2}$$

$$b = \frac{378{,}816.88}{2366}$$

$$b = 160.1085714$$

Similarly

$$a = \frac{\Sigma y}{n} - \frac{b\Sigma x}{n}$$

$$a = \frac{99481.68}{13} - \frac{160.1085 \times 0}{13}$$

$$a = 7{,}652.436923$$

Therefore; $Y = 7652.43 + 160.10x$; the trend values are given below:
Now substituting all the value from 1st year to 20th years, look ahead period and we have the trend values as:
$Y = 7653.43 + 160.1x$

Table 3: 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	7910.08	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**

$Y(2000) = 7653.43 + 160.10(-6)$
$Y(2000) = 7653.43 + -960.6 = 6691.83MW$
$Y(2001) = 7653.43 + 160.10(-5)$
$Y(2001) = 7653.43 + -800.5 = 685.93MW$
$Y(2002) = 7653.43 + 160.10(-4)$
$Y(2002) = 7653.43 + -640.4 = 7012.03MW$
$Y(2003) = 7653.43 + 160.10(-3)$
$Y(2003) = 7653.43 + -480.3 = 7172.13MW$
$Y(2004) = 7653.43 + -160.10 = (-2)$
$Y(2005) = 7653.43 + -320.20 = 7172.13MW$
$Y(2005) = 7653.43 + 160.10(-1)$
$Y(2005) = 7653.43 + 160.10 = 7492.33MW$
$Y(2006) = 7653.43 + 160.10(0) = 7653.43MW$
$Y(2007) = 7653.43 + 160.10(1)$
$Y(2007) = 7653.43 + 160.10 = 7812.53MW$
$Y(2008) = 7653.43 + 160.10(2)$
$Y(2008) = 7653.43 + 320.2 = 7972.63MW$
$Y(2009) = 7653.43 + 160.10(3)$
$Y(2009) = 7653.43 + 480.3 = 8132.73MW$
$Y(2010) = 7653.43 + 160.10\ (4)$
$Y(2010) = 7653.43 + 160.10 = 8292.83MW$
$Y(2011) = 7653.43 + 160.10(5)$
$Y(2011) = 7653.43 + 800.5 = 8452.93MW$
$Y(2012) = 7653.43 + 960.6 = 8613.03MW$

Now the forecast values can be obtained from Y(2013) – Y(2032), from our previous relationship:
$Y = 7653.43 + 160.10(x)$
$Y(2013) = 7653.43 + 160.10(7)$
$Y(2013) = 7653.43 + 1120.7 = 8773.13MW$
$Y(2014) = 7653.43 + 160.10(8)$
$Y(2014) = 7653.43 + 1280.8 = 8933.23MW$
$\vdots \quad \vdots \quad \vdots \quad \vdots$
$Y(2032) = 7653.43 + 160.10(26)$
$Y(2032) = 7653.43 + 4162.6 = 11815.03MW$

Table 4: Table of 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	11104.53
2028	11174.63
2029	11334.73
2030	11494.83
2031	11654.93
2032	11815.03

5. Commercial Demand

The commercial demand forecast is performed using the data below: computation of commercial load demand using regression analysis techniques.

Table 5: The Commercial Demand

YEAR	X	COMMERCIAL DEMAND (MW)Y	XY	X^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	-	9

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			10749.00	
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	20023.59	25
2012	6	4025.40	24152.40	36
TOTAL	**0**	**46836.1**	**21372.69**	**182**

From our straight line (trend line) given by:

From $Y = a + bx$ (1)

Where; $a = \frac{\Sigma y}{n} - \frac{b\Sigma x}{n}$ = trend line value, (2)

$$b = \frac{n\Sigma xy - \Sigma x\Sigma y}{n\Sigma x^2 - (\Sigma x)^2} \qquad (3)$$

Substituting the data into equation (1,2 & 3) we have:

$$\Sigma xy = 2137269$$
$$\Sigma x = 0$$
$$\Sigma y = 4836.1$$
$$\Sigma x^2 = 182$$
$$n = 13$$

$$b = \frac{n\Sigma xy - \Sigma x\Sigma y}{n\Sigma x^2 - (\Sigma x)^2} = \frac{13 \times 21372.69 - 0 \times 46836.1}{13 \times 182 - 0^2}$$

$$b = \frac{277{,}844.97}{2366}$$

$$b = 117..4323626$$

Similarly

$$a = \frac{\Sigma y}{n} - \frac{b\Sigma x}{n}$$

$$a = \frac{46836.1}{13} - \frac{117.4323626 \times 0}{13}$$

$$a = 3{,}602.776923$$

$$a = 3{,}602.776923$$

Therefore; $Y = 3{,}602.78 + 117.43x$; the trend values are given below:

Now substituting all the value from 1st year to 20th years, look ahead period and we have the trend values as:

$$Y = 3{,}602.78 + 117.43x$$

Table 6: Table of Values For Actual Commercial Demand

YEAR	COMMERCIAL DEMAND (MW) y	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**

Table 7: Table of Values for Commercial Demand Forecasted

YEAR	COMMERCIAL FORECASTED DEMAND Y (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
2031	6538.52
2032	6655.95

6. Industrial Demand

The industrial demand forecast is performed using the data below: computation of industrial load demand using regression analysis techniques.

Table 8: Table of Values for Industrial Demand

YEAR	X	INDUSTRIAL DEMAND (MW)Y	XY	X^2
2000	-6	1011.60	- 6069.60	36
2001	-5	1987.20	- 9936.00	25

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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**

From our straight line (trend line) given by:

From $Y = a + bx$ (1)

Where; $a = \frac{\Sigma y}{n} - \frac{b\Sigma x}{n}$ = trend line value,

$$b = \frac{n\Sigma xy - \Sigma x \Sigma y}{n\Sigma x^2 - (\Sigma x)^2} \quad (2)$$

Substituting the data into equation (1,2 & 3) we have:

$$\Sigma xy = 480.10$$
$$\Sigma x = 0$$
$$\Sigma y = 20755.00$$
$$\Sigma x^2 = 182$$
$$n = 13$$

$$b = \frac{n\Sigma xy - \Sigma x \Sigma y}{n\Sigma x^2 - (\Sigma x)^2} = \frac{13 \times 483.10 - 0 \times 20755.00}{13 \times 182 - 0^2}$$

$$b = \frac{6,280.3}{2366}$$

$$b = 2.65439$$

Similarly

$$a = \frac{\Sigma y}{n} - \frac{b\Sigma x}{n}$$

$$a = \frac{20755.00}{13} - \frac{2.65439 \times 0}{13}$$

$$a = 1,596.538$$

Therefore; $Y = 1,596.54 + 2.6544x$; the trend values are given below:

Now substituting all the value from 1st year to 20th years, look ahead period and we have the trend values as:

$$Y = 1,596.54 + 2.6544x$$

Table9: Table of Values of Actual Industrial Demand

YEAR	INDUSTRIAL DEMAND (MW) y	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**

Table 10: Table of Forecast Values For The Future Industrial Load Demand

YEAR	INDUSTRIAL FORECASTED DEMAND Y (MW)
2013	1615.08
2014	1617.73
2015	1620.83
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	1652.88
2026	1649.53
2027	1652.18
2028	1654.83
2029	1657.48
2030	166
2031	1662.78
2032	1665.43

7. 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 11: 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
2031	19856.23
2032	20136.41

Generating Station Percentage Contribution to the National Grid

Table 12: Percentage Distribution

GENERATING STATION	PERCENTAGE DISTRIBUTION
Egbin Power Station (FGN)	14.87%
Shiroro Power Station (hydro FGN)	6.76%
Ughelli Power Station (FGN)	9.15%
Kainji Power Station (Hydro FGN)	8.56%
Sapele Power Station (NIPP)	11.49%
Afam Power Station IV – VI (FGN)	11.04%
Afam IV Power Station (IPP)	7.32%
Jebba Power Station (NIPP)	6.09%
Geregu Power Station (NIPP)	4.96%
Omotosho Power Station (NIPP)	3.43%
Olorunsogo Power Station (NIPP)	3.43%
AES Power Station (IPP)	3.04%
Okapi Power Station(IPP)	5.07%
Omoku Power Station (NIPP)	1.69%
Trans-Amadi Power Station (NIPP)	1.53%
Geometric Power Station (FGN)	**1.58%**
Total	**100%**

Generating Station Capacity Contribution to the National Grid

Table 13: Capacity Distribution

GENERATING STATION	PERCENTAGE DISTRIBUTION
Egbin Power Station (FGN)	2995MW
Shiroro Power Station (Hydro)	1361MW
Ughelli Power Station (	1842MW
Kainji Power Station (Hydro)	1724MW
Sapele Power Station (NIPP)	2314MW
Afam Power Station (FGN)	2223MW
A fam VI Power Station (IPP)	1475MW
Jebba Power Station (	1226MW
Geregu Power Station	998MW
Omotosho Power Station	690MW
Olorunsogo Power Station	690MW
AES Power Station	613MW
Okapi Power Station	1021MW
Omoku Power Station	340MW
Trans-Amadi Power Station	309MW
Geometric Power Station	318MW
Total	**20,136.41MW**

Conclusion

Electricity supply particularly in Nigeria, is grossly inadequate the total installed capacity is far less than the energy demand, this means that there is violation of the equality constraints condition and mismatches in the power system. The load forecast analysis considered a long term planning of twenty years (20yrs) projection periods. The essence of the load forecast results is to know the capacity energy generation to be produced at different generating station.

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