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Load Forecast Model for an Insufficient Power Supply in A Developing Area. A Case Study of Abakaliki Capital Territory

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Abstract

This paper discusses the deficiencies in the use of historical load demand in regression equations for load forecasting for an area supplied by a utility that has insufficient power generation. It also suggests ways to remedy these deficiencies. The power demand of Abakaliki capital territory of Ebonyi state of Nigeria was used in this paper.
Keywords: load forecast, extrapolation, load survey, connected customer, unconnected load, peak demand.

1.0 Introduction

Forecasts are made on the basis of past load growth by extrapolating for future [1]. When a power utility has sufficient power generation for meeting the energy demands of her customers in a given area, forecasting the future load demands for such area based on the history of their load demands comes into play. However, when supply utility has insufficient power generation capacities to meet the load needs of her customers, the history of the load demands for the area alone gives no suitable result.

Study was conducted in Abakaliki capital territory of Ebonyi state of Nigeria, an area supplied by the utility company - Enugu Electricity Distribution Company (EEDC). Nigeria's electricity generation capacities are far below the consumer's demands; hence the power made available to the distribution company – EEDC, is far lower than what is demanded from it. The result of this is that, the historical load data gotten from the utility company is not a true reflection of the load demands of the area as seen during the survey.

2.0 Load Survey

The load demand survey carried out in Abakaliki capital territory for the period of year 2006 to year 2014 revealed the followings:

2.1 Yearly Peak Load Demand of Connected Customers

From the data available in the supply company, the yearly peak demand for the period is as shown in table 1 below.

Table 1 Historical yearly peak load demand in Abakaliki capital territory from year 2006 to 2014

Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Peak power demand in the capital territory (MW)	27.5	23.9	24.5	27.5	28.6	31.5	33.9	36.9	37.6

2.2 Unconnected Loads

It was discovered that the supply utility does not have the capacity to meet the load demands of their customers, the supply becomes epileptic and of low quality. As a result, many customers of the EEDC have resorted to the use of their personal generator sets. Among this category are:

(A) Abakaliki rice mill with total load of 47.36MW.
(B) Some small scale industries totaling 0.6MW.
(C) Royal salt mining company with load capacity of 4.0MW

2.3 Nearly Completed State Government Projects

Nearly completed state government projects capable of causing sudden high rise in load demands were also discovered. Notable among this category are:

(A) Ocho-Udo city project with demand capacity of 5.5MW
(B) The regional market project with demand capacity of 4.0MW
(C) Street lighting project with demand capacity of 0.5MW

The load capacity of these nearly completed state government projects is 10.0MW.

3.0 Analysis of Load Survey Report

3.1 Historical Load Data

A graph of the historical load data given in table 1 above gives us a graphical picture of the load growth pattern. The sketch is shown in figure 1 below.

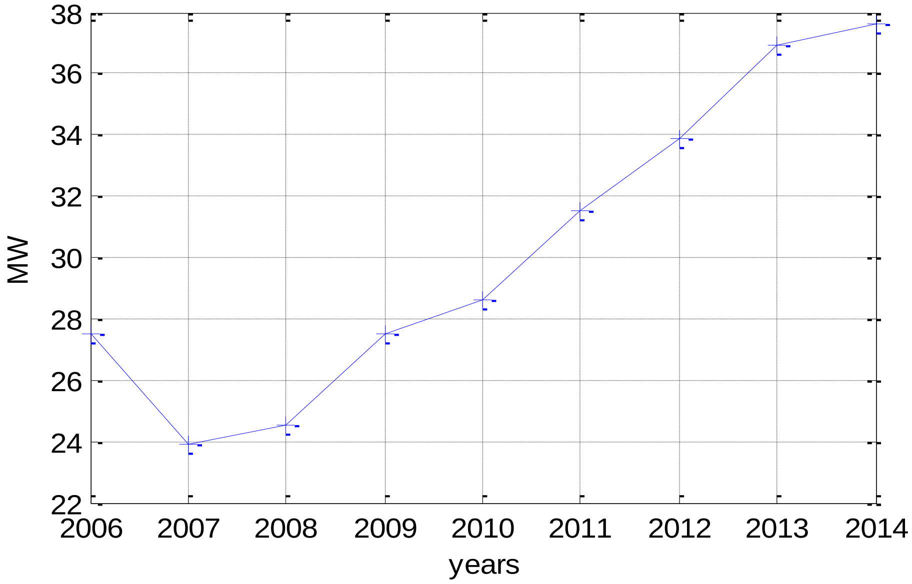

Figure 1: Graph of peak load against year (Load growth pattern)

As seen from figure 1 above, a linear curve fits the growth trend appropriately, such that the following equation suits in a regression analysis:

$Y = b_0 + b_1X$ ------ (1)

Where

Y = demanded power

X = year (2006 = 1; 2007 = 2; 2008 = 3; and so on).

$b_0, b_1,$ = constants determined by least square method as:

$b_0 = 21.6944$

$b_1 = 1.7033$

Substituting the values for b_0 and b_1 in equation (1) gives

$Y = 21.6944 + 1.7033X$

Such that the projected load for year 2015 = 38.7278MW; year 2016 = 40.4311MW; year 2020 = 47.2444MW; year 2030 = 64.2778MW; year 2034 = 71.0911MW; year 2040 = 81.3111MW. This is shown in figure 2 below.

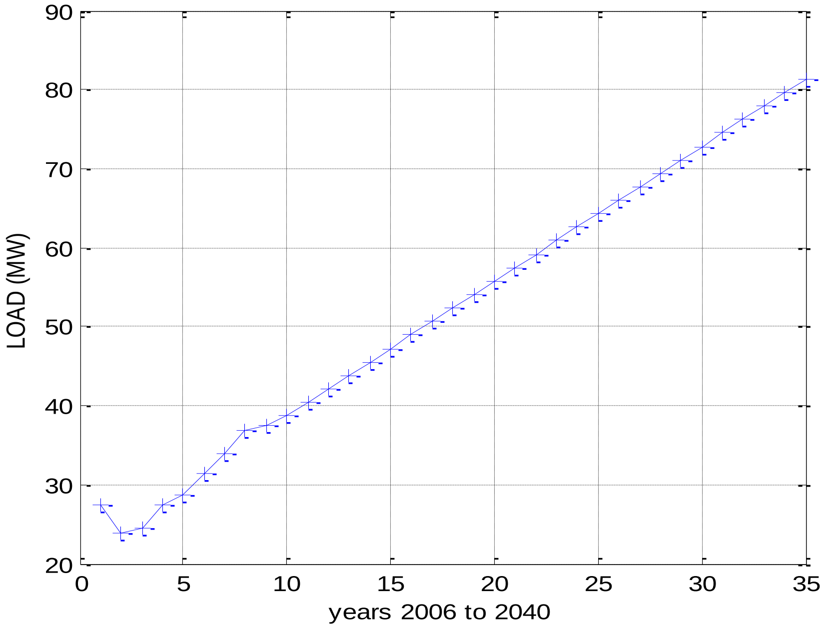

Figure 2: Projected load without correction

Since the essence of this forecast is to enable the government (client) plan how to boost the insufficient power generation to meet the demand of the population in future times, the result of this forecast may cause the state government (client) to plan below their actual (true) demand.

3.2 Actual Present Power Needs of the Capital

The present power demand in the capital territory is not what was seen in the historical data but actually:

Abakaliki rice mill load of 47.36MW + small scale industries load totaling 0.6MW + Royal salt mining company load of 4.0MW = 51.96MW

Applying a demand factor of 0.5 on this implies 51.96 x 0.5

= 25.98 MW

And adding year 2014 recorded peak load of 37.6MW to the above gives 25.98 + 37.6 = 63.58MW

Commissioning Ocho-Udo city project, the regional market project and the street lighting project totaling 10.0MW as planned by the state government in the first quarter of year 2015 further takes up the load to 70.58MW (i.e. 63.58 + [10 x 0.7]), where 0.7 is the demand factor of the group [2, 3, 4].

4.0 Discussion

4.1 Actual Power Needs at Year 2014 Compared With Projection Based on Historical Data

The actual power needs as at year 2014 is 63.58MW. Comparing this value to the projected load based on the historical load data, one observes that this is about the same with the projected load for year 2030, sixteen years ahead.

At the first quarter of year 2015, the actual power needs is 70.58MW, which is about equal to the value projected for year 2034. This error is much and cannot be neglected.

A correction factor should therefore be introduced in order to keep the regression formulae valid in this situation.

4.2 Correction Factor

There were three parts in the load survey:

(A) Available load connected to the public power source.
(B) Available load not connected to the public power source.
(C) Nearly completed projects capable of causing sudden high load rise in the near future.

The regression equation ($Y = b_0 + b_1X$), given in equation (1) satisfies part 4.2(A) while part 4.2(B) and (C) are not satisfied unless it is modified as follows:

$$Y = [b_0 + b_1X]\, c + [b_0 + b_1X]\, d$$

$$= [b_0 + b_1X]\,(c + d) \text{ ----- (2)}$$

Where

c and d = correction factors that are determined as shown below. c gives correction for 4.2(B) while d offers correction for 4.2(C):

(i) Find the ratio of unconnected load to the connected load, PUL.
(ii) Find the total load growth between first year and last year, TLG.
(iii) Find the average load growth, ALG = TLG/ (year last minus year one).

$c = 1 + PUL$

$d = 0.05ALG$

Using values from the case at hand,

$PUL = 25.98/37.6$

$= 0.69$

OR

$c = 1.69$

And

$d = 0.05ALG = 0.05[(37.6 – 27.5)/ (2014 – 2006)]$

$= 0.05[10.1/8]$

$= 0.063$

Substituting c and d in equation (2) gives 65.9128MW for year 2014 and 67.8898MW for year 2015 as seen in figure 3 below.

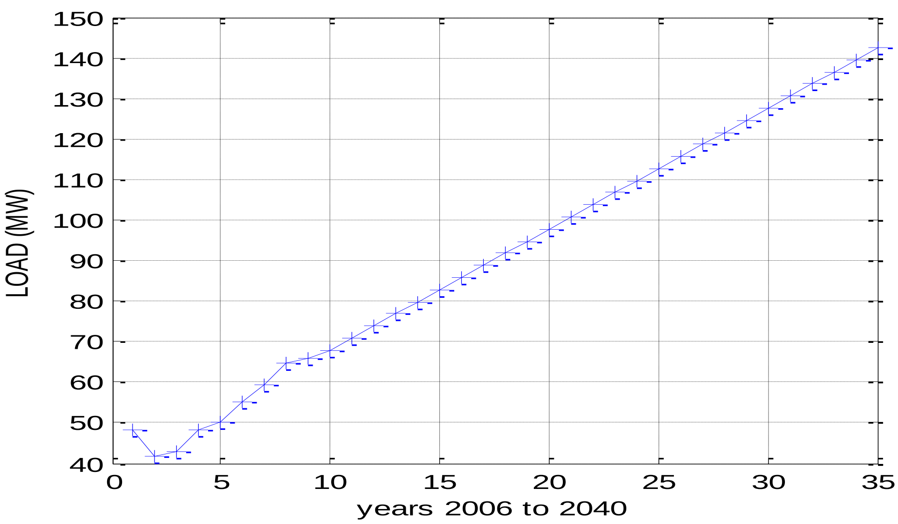

Figure 3: Projected load with correction

The rice mill and the salt company were out because; the supply authority could not meet their demand. They are now assumed to have been connected since the year 2006. By this, the unconnected load (25.98MW) are added to the historical data such that table 1 becomes table 2 below.

Table 2: Unconnected load added to the historical data

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014
Peak power demand in the capital territory (MW)	53.48	49.88	50.48	53.48	54.58	57.48	59.88	62.88	63.58

The projected load from table 2 using equation (1) is as shown in figure 4 below.

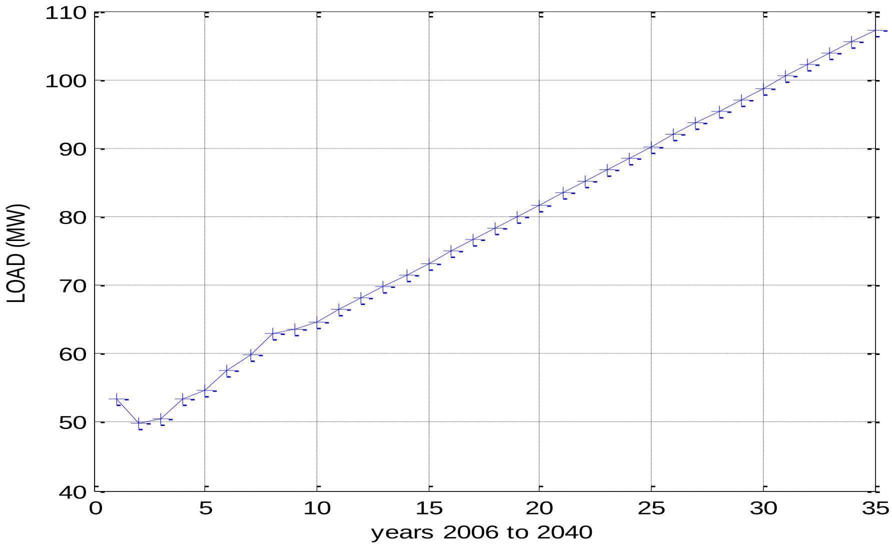

Figure 4: Projection with unconnected load assumed connected

Equations (1) and (2) are compared graphically in figure 5 below.

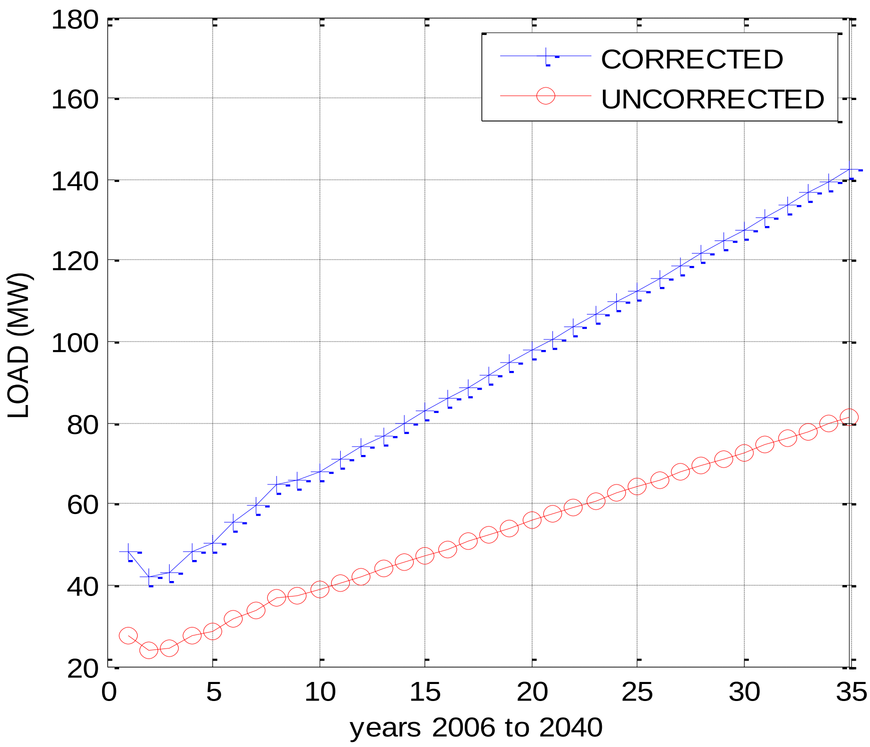

Figure 5: Projected load with correction and without correction

Figure 5 shows clearly that equation (2) is superior to equation (1) and gives satisfactory result in circumstances like the one being considered in this paper.

Equation (2) will further be better appreciated with the comparison given in figure 6 and table 3 below.

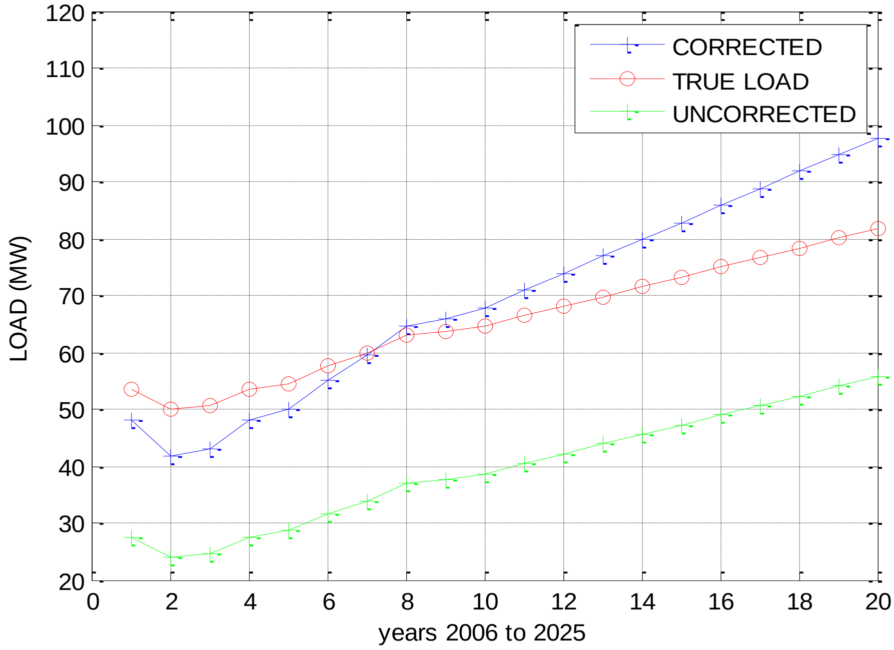

Figure 6: Projected load with correction, without correction and true load

Table 3: The effect of equation (2) examined

YEAR	EQUATION (1) USED FOR THE CONNECTED LOAD ONLY	EQUATION (2) USED FOR THE CONNECTED LOAD ONLY	EQUATION (1) USED FOR THE CONNECTED LOAD ADDED TO THE UNCONNECTED LOAD
2015	38.7278	67.8898	64.7078
2016	40.4311	70.8757	66.4111
2017	42.1344	73.8617	68.1144
2018	43.8378	76.8476	69.8178
2019	45.5411	79.8336	71.5211
2020	47.2444	82.8195	73.2244
2021	48.9478	85.8055	74.9278
2022	50.6511	88.7914	76.6311
2023	52.3544	91.7773	78.3344
2024	54.0578	94.7633	80.0378
2025	55.7611	97.7492	81.7411

From both figure 6 and table 3 a large difference is observed between the cases when equations (1) and (2) were used on the data obtained from the load survey, the result from the use of equation (1) being lower than realities (the effect of unconnected load and nearly completed projects).

Also from both figure 6 and table 3, there is just a little difference when the result from the use of equation (2) on the historical load data is compared to when equation (1) was used on the historical load data but with the value of the unconnected load added to each of them. The result from the use of equation (2) being higher confirms a better result noting that the effect of the unconnected load on the load demand trend should not have been constant as assumed here, since the year 2006 till date.

4.3 The Validity of the Correction

The formula is valid for use in all regression equations – linear, curvilinear, exponential, etc. When there are no nearly completed projects capable of causing sudden high rise in power demand, set d = 0 such that with PUL = 0, the original regression equation is left.

For a polynomial curve of degree 2, equation (2) shall be written thus:

$$Y = [b_0 + b_1X + b_2X^2] (c + d) \text{ ------ } (3)$$

5.0 Conclusion

This paper presented the deficiencies in the use of historical load data in regression equations for load forecasting in an area supplied by a utility that has insufficient power generation.

Apart from the historical load data, other things to look out for when the area in question has similar challenges as the one considered are:

(i) Unconnected load due to insufficient generation and

(ii) Projects nearing completion that are capable of causing sudden high rise in power demand.

The modified regression equation introduced here are valid and should be useful to planners in areas with challenges similar to that in Abakaliki capital territory of Ebonyi State of Nigeria.

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