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(RESEARCH ARTICLE)

Forecast of the electrical energy demand of N'Djamena, Chad, based on the statistical method

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Abstract

We study the forecast of the electrical energy demand of the N'Djamena city, Chad, by 2032 using the statistical model based on the linear regression technic. A series of data of the maximum power demand (PMA) for the past years from 2005 to 2017 are obtained from the dispatching center of the company national electricity board of N'Djamena, which allow us to make energy projection from 2018 to 2032. Then these data are analyzed by the statistical method of linear regression forecast. The results obtained by the linear regression are closed to that provided by the Excel trend curve and they have a strong linear correlation coefficient of 0.963 between the maximum powers estimated and the given years. In addition, the predicted power peak needed by electricity consumers by 2032 is 175 MW compared to 90 MW in 2017, meaning that in 15 years, the consumption of electrical energy will pass from simple to double.

Keywords: Electrical energy; Forecast; Statistical method; Generation fleet; Peak power

1. Introduction

The economic growth of every nation is strongly linked to its electricity infrastructure, and its availability since electricity has become the central element of daily life in the modern world [1]. The 21st century presents itself as a century of technological advances for which electrical energy is necessary. Therefore all the electricity companies forecast the demand for electrical energy in order to mobilize the adequate infrastructure to satisfy subscribers. Chad has a low electricity access rate, 6.4% with a large disparity between the capital N'Djamena (35%) and the other provinces (1%) [2]. Given the economic growth and the current pressing demand for electricity in N'Djamena, the national electricity company (SNE) must provide the infrastructure for the production, transport and distribution of electricity to achieve a rate of access to electricity of 50% by 2032[2].

To meet the energy needs of a region or a country within a given horizon, some forecasting methods use statistical models (regression and series chronological) while others are based on the calculation using intelligent models (networks of neurons, fuzzy neurons). Other techniques for predicting electrical loads are addressed in the literature as the hybrid [3] and multi-resolution [4] approaches. All these state-of-the-art power demand forecasting methods are categorized into depending on the length of time: Daily or short-term forecasts for the peak load varying from several

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hours to a few days < 7 [3- 11]. Weekly and monthly or even medium-term forecasts concern the peak load from a few weeks to a few months [3-15]; Annual or long-term forecasts used the maximum demand is more than one year [6, 16].

The maximum load demand forecast model will use the peak hour daily as a variable. Errors in peak demand forecasting models can be determined by the mean absolute error (MAE), the mean squared error (MSE), or the root mean square error (RMSE). The most popular statistical method uses a series of past chronological data to predict the future from mathematical models [8, 16- 19]. The networks of artificial neurons (ANN) are recurrent in the prediction of electrical charge especially when several variables are involved [10-12, 15, 20- 23]. The results of all these analytical methods are often compared with data provided by electric power producers. The aim of this work is to propose the forecast of the peak of the electrical energy demand of N'Djamena, Chad by 2032, by a statistical approach based on the history of the maximum powers. The mathematical model associated with the method of analysis is the linear regression

2. Materials and methods

Let us consider about ten of the historical data of maximum powers needed by the city of N'Djamena provided by the SNE as well as the total production capacity of 2022.

2.1. Identification of the study city N'Djamena

N'Djamena is both the political capital and in addition a region of Chad. Its population is estimated at 1.5 million in 2022. The map as shown in Fig.1 shows the location of the city N'Djamena in Chad.

Figure 1 Chad map, located in central Africa

2.2. Collection of data

The national production of electricity is ensured by power stations of the national company of electricity, powered only by diesel (Diesel) and concentrated mainly in N'Djamena [2]. Chad does not have a national electricity grid, each region is autonomous, and therefore no electricity transmission network. Only N'Djamena has a transmission line of about twenty kilometers of the national society of petroleum refinery. Table 1 shows the study period and different capacities.

2.3. Statistical method

The forecast study of electrical loads by 2032 for the city of N'Djamena is determined by the statistical method. The associated mathematical model is defined by the linear regression giving y as a function of x [24, 25]:

$$y = \beta + \alpha x, \quad ....(1)$$

Table 1 Study period and different capacities

Period of study	Production capacity (MW) 2022	Transmission line capacity (MW) 2022	Number of low voltage distribution substations
2005 to 2021	100	135	612

Where α and β are constants to be determined by the least squares method. And where y denotes the power peak for a year x. Let us consider a cloud of points $\boldsymbol{M_i(x_i, y_i)}$ that we want to adjust as well as possible by an affine function$\boldsymbol{y} = \boldsymbol{f(x)}$. We find the parameters of f(x) by minimizing the sum of the squares of the distances between y_i and $f(x_i)$, in other words the error:

$$\sum_{i=1}^{n} \delta_i^2 = u(\alpha, \beta) = \sum_{i=1}^{n} (\alpha x_i + \beta - y_i)^2 \text{.....................} \qquad (2)$$

The determination of α and β consists in the minimizing of Eq.(2) with respect to α and β: That is $\frac{\partial u}{\partial \alpha} = \frac{\partial u}{\partial \beta} = 0$, leading to

$$\beta = \overline{y} - \alpha \overline{x}, \alpha = \frac{cov(x,y)}{V(x)}, \qquad \text{....................} \; (3)$$

with

$$\overline{x} = \frac{1}{n} \sum_{i=1}^{n} x_i \, , cov(x,y) = \frac{1}{n} \sum_{i=1}^{n} x_i y_i \; - \overline{xy}, V(x) = \frac{1}{n} (\sum_{i=1}^{n} x_i^2 \,) \; - \overline{x}^2. \; \text{........} \; (4)$$

The linear correlation coefficient of the point (x, y) is given by:

$$R = \frac{cov(x,y)}{\sqrt{V(x)V(Y)}}. \qquad \text{.....................} \qquad (5)$$

Let us notice that:

• The regression line passes through the center of gravity of the cloud, that is the mean point $(\boldsymbol{\overline{x}}, \boldsymbol{\overline{y}})$

• The linear correlation coefficient R can satisfy the following inequality: $-1 \le R \le 1$.

• $\boldsymbol{R^2 = 1}$ $(R = \pm 1)$, All the points are aligned on the regression line.

• $R = 0$, The model does not explain anything, the variables x and y are not linearly correlated.

• $R > 0.87$, the linear fit is relevant

3. Results and discussion

Recent SNE historical data and the above statistical method allow to obtain the following results

3.1. Maximum power demand data (PMA)

The dispatching center of the transport and distribution department and the basic service of SNE data provided LDC data from the city of N'Djamena from 2005 to 2017 summarized in the table 2.

Table 2 Maximum power demand from 2004 to 2021

Year (x_i)	2005	2006	2007	2008	2009	2010	2015	2016	2017
P(MW) (y_i)	21,77	22,32	33,34	24,19	24,19	36,86	69	82	90

3.2. Determination of maximum power demand

The dispatching center newly installed in 2015 leads to the collection of data from electrical energy consumption in N'Djamena. Electricity consumption peaks are observed in summer, a hot period, due to the start-up of air conditioners, ice cream factories and large fans. The data of the electrical powers obtained during the months from March to June of both two years 2016 and 2017 as well as that of the days of October 2015 allow us to draw the graph of loads to identify the day and time where the power peak is reached.

3.2.1. Determination of the busiest day

This part allows identifying, over the four months of summer heat, the day when the power needed is maximal. Figures 2 and 3 show the consumption peak of the month of the years 2016 and 2017, respectively.

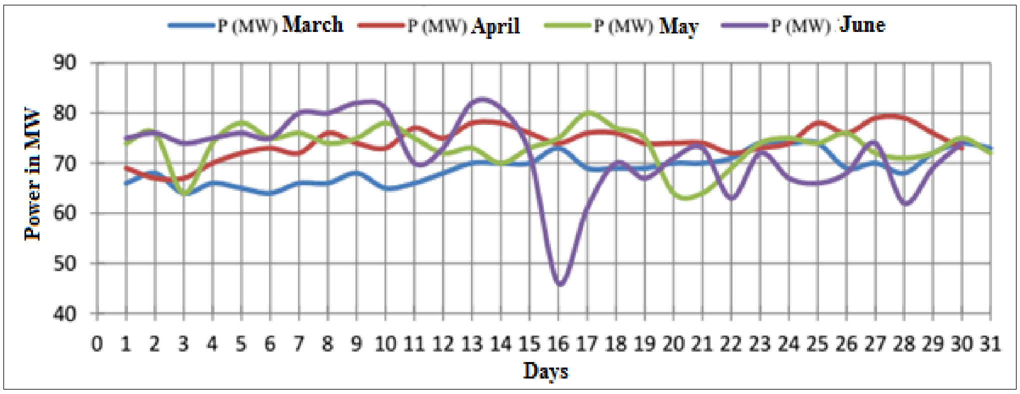

Figure 2 Monthly load of March, April, May and June 2016

The analysis of Figure (2) shows that the month of June is the busiest with a maximum power of 82 MW recorded on June 13 and the least loaded with a minimum of 47 MW observed in June 16. In addition, throughout the heat period from the beginning of March to the end of June, the power peak oscillates between 62 and 82 MW with the exception of June 16. This sudden drop in power can be explained by breakdowns of certain generating sets or faults fuel supply, causing the shutdown of some generators monitoring of load shedding on the network.

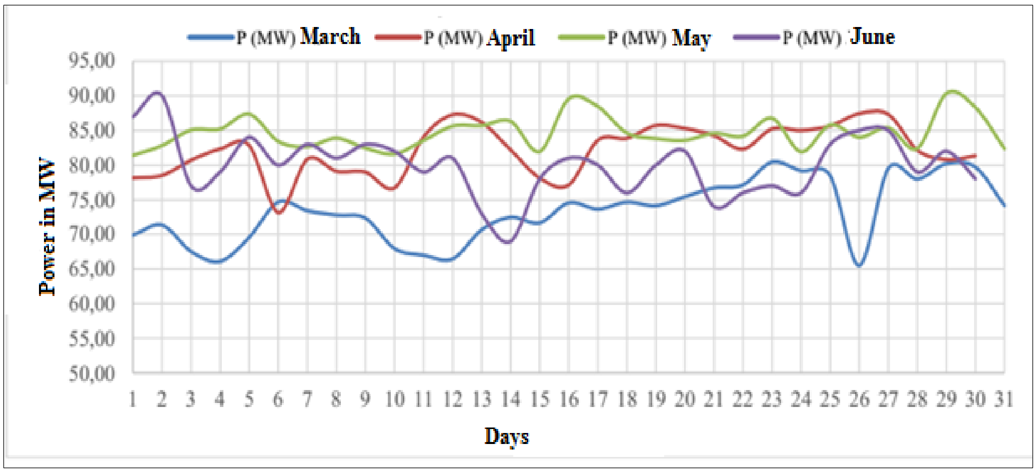

Figure 3 Monthly loads for the months of March, April, May and June 2017

Figure (3) obtained for the year 2017 shows the power peak of 90 MW which is reached respectively on May 29 and June 2. However any electricity consumption for the month of May varies between 80 and 90 MW, which justify that the month of May is the busiest. During the summer period, the maximum power demand is between 66 and 90MW.

3.2.2. Rush hour determination

The data giving the high electricity consumption as a function of days allows the identification of the time peak in each of the last three years 2015, 2016 and 2017 as shown in Figure (4). The year 2015 marks the beginning of the dispatching center where the power peak of 69 MW was recorded on October 15. The peak powers of October 2015, June 2016 and May 2017 have been reached respectively at 2 p.m., 2 p.m. and 10 p.m.

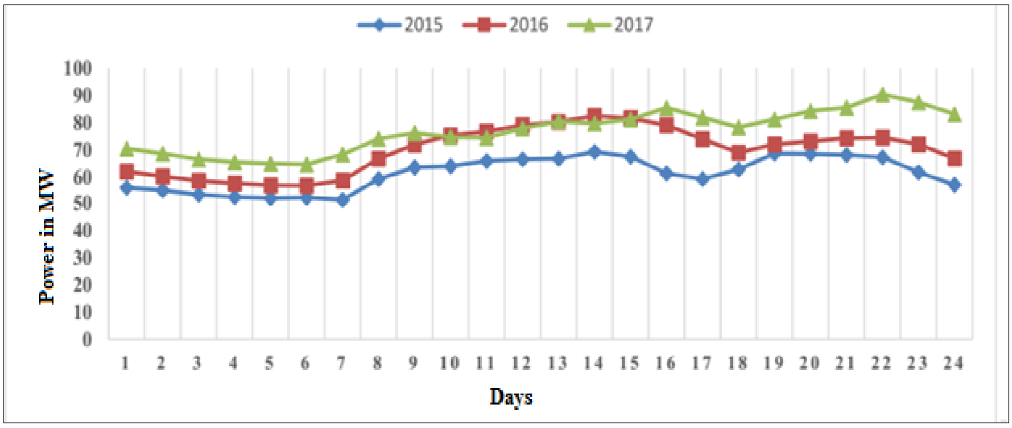

Figure 4 **D**aily power loads for the months October 2015, June 2016 and May 2017

3.3. Load power forecasts

3.3.1. Determination of the line of regression

According to Table 2 and equations (3) to (9), it is possible to determine the covariance $COV(X,Y)$, the variances V(X) and V(Y), the coefficients α, β and R.

Table 3 Different coefficients

COV(X,Y)	V(X)	V(Y)	α	β	R
106,858	18,222	676,905	5,8642	-11744	0,9621

The regression line given y as a function of x thus has the equation y = 5.8642x – 11744. To make a comparative study between the regression line equation of the statistical method, and the equation of the trend line given by Microsoft Excel, data of Table 2 can be used to plot the scatter plot and trend line as shown in the figure 5:

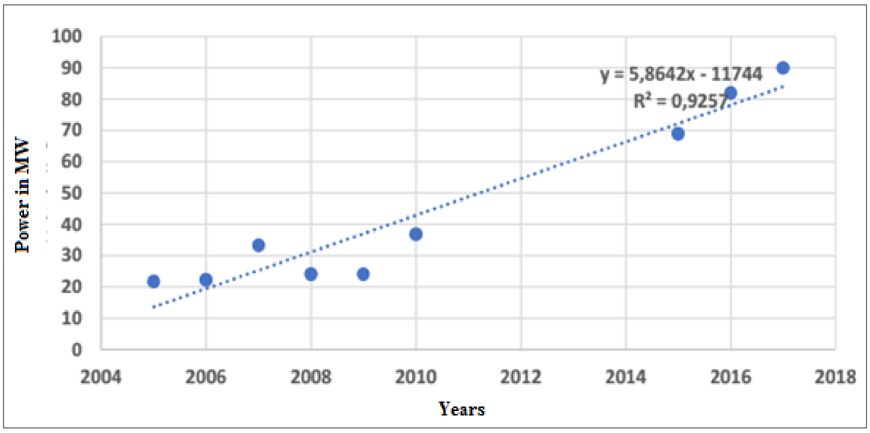

Figure 5 Regression line y=f(x)

The equation obtained by the least squares method and that of the trend obtained by Excel are the same. In addition, there is a good correlation between the maximum values of power needed and the years since the coefficient $R = 0.9621$ is closed to unity, leading that the point cloud fits well around the regression line.

3.3.2. Projection of maximum power demand

The extrapolation of the regression line indicates that the maximum power demand increases linearly with an average of 5.5 MW per year. In fifteen years the power peak is at least twice that of 2015. For by 2032, the need for the city of N'Djamena in electrical energy quantified in maximum power will be around 172 MW.

4. Conclusion

The forecast of the electrical energy demand of the N'Djamena city, Chad, by 2032 has been studied using the statistical model based on the linear regression. The correlation coefficient value between the maximum power demands obtained both experimentally and by prediction and the corresponding years is closed to unity, which explains a good agreement between the measured power values and the adjusted ones. Thus the maximum power demand of the city of N'Djamena can reach easily 175 MW in 2032. So the national electricity company and the political decision-makers must plan the construction of new power plants with an active power of at least 75 MW or 100 MW, to increase the electricity transmission capacity to 200 MW and to increase the number of poles and medium voltage lines as well as low voltage distribution stations to meet the needs of future consumers in 2032.

NES managers, political decision-makers as well as technical and financial institutions involved in the project can know the capacities relating to the works of generation, transmission and distribution of electrical energy. This work can be used to predict electrical powers to other towns in Chad.

Compliance with ethical standards

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Disclosure of conflict of interest

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version. Additionally, there are no conflicts of interest in connection with this paper, and the material described is not under publication or consideration for publication elsewhere.

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