Electricity Consumption Forecast of Hunan Province Using Combined Model Based on Multivariate Linear Regression and BP Neural Network

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Keyword: Multivariate linear regression; BP neural network; Combined model; Electricity consumption forecast of hunan province

Abstract. In recent years, the low energy consumption level and shortage of energy resources have become key factors restricting energy development and structural adjustment of Hunan Province. Therefore, load forecasting does play a significant role in making reasonable grid plan for Hunan Province. In this paper, by collecting and analyzing data of Hunan Power Grid, we identified the factors affecting electricity consumption, and then used multiple linear regression method and BP neural network to predict the electricity consumption in the next nine years. The results showed that, the growth rate of electricity consumption of Hunan Province in next nine years is lower than that of the past ten years.

Introduction

Electricity load forecasting is not only a prerequisite for grid design, but also an important basis for the grid planning. Therefore, it is of great significance to choose appropriate forecasting methods and gradually improve the electricity load forecasting accuracy to improve power grid planning quality.

Located in the transitional place of eastern coastal area and the mid-western, and the intersection of the Yangtze River economic development zone and the coastal open economy zone, Hunan occupies an important position in the regional development of the country. In the "Energy Development Plan of Hunan Province in the 13th Five-Year", the government pointed out the problems of energy consumption of Hunan Province, including lack of resources, low level of energy consumption capacity, weak transmission channel and so on, and proposed to enhance the efficient convergence between power plants and power grid construction to ensure reliable operation of power grid on the premise of security protection [1]. Therefore, it is crucial for Hunan Province to complete the energy development plan by analyzing current development status of power grid, doing power load forecasting work to meet the needs of national economy and social development.

Electric load forecasting technology has basically gone through three development stages: (1) classic load forecasting, mainly includes the electric elasticity coefficient method, load density method， proportion coefficient method and other methods; (2) traditional load forecasting, mainly includes trend extrapolation method, time series analysis and regression model; (3) modern load forecasting, mainly includes gray prediction technology, support vector machine, system dynamics, neural network algorithm, swarm algorithm, simulated annealing algorithm and so on[2]. In addition, optimal combination forecasting methods are also commonly-used today, which work based on single forecasting methods. A great number of scholars combined neural network and gray system theory with other algorithms to carry out load forecasting [3-7].

In view of the social and economic development status of Hunan Province, in this paper, we use the combined forecasting model of multiple linear regression method and BP neural network to predict the energy consumption in Hunan Province. The rest of the paper is structured as follows: section 2 analyzes the factors that affect electricity consumption in Hunan Province; section 3 predicts the electricity consumption of Hunan province on the basis of the former two sections; section 4 summarizes the work.

Analysis of Factors Affecting Electricity Consumption of Hunan Province

Electricity Demand Analysis. According to the data related to electricity consumption and other information, the relationship between electricity consumption and GDP, economic structure and other factors can be analyzed.

Analysis of historical annual electricity consumption and GDP

During 2005 to 2016, Hunan Province's GDP has been steadily increasing, growing at an annual average rate of 13.10% from 659.1 billion yuan in 2005 to 312.447 billion yuan in 2016, and the electricity consumption has basically risen steadily as well. From 2006 to 2008, influenced by the global economic crisis and snow disaster, the growth of electricity consumption was at a relatively low level; from 2008 to 2013, the electricity consumption steadily increased; after 2013, though the electricity consumption increased, the growth rate was lower than that of the previous years, which was consistent with the background of a slowdown of China's economic growth.

Analysis of per capita electricity consumption and resident population

From 2005 to 2016, the resident population in Hunan Province fluctuated slightly, but overall showed a slight upward trend, which increased from 640.1million in 2005 to 682.2 million in 2016 with a growth rate of 6.56%. From the perspective of electricity consumption, the per capita electricity consumption increased steadily during the observation period, from 819.50kWh / person in 2005 to 2192kWh / person with a total growth rate of 167.48%. This shows that with the development of the national economy and society, the large growth of electricity consumption results in a substantial increase in the electricity consumption per capita under the background of small change in population.

Analysis of electricity consumption per unit output value

As a whole, the electricity consumption per unit output value of the three industries all shows a downward trend. Among them, the electricity consumption per unit output value of the secondary industry is most significant, dropping from 1,454.93kWh / ten thousand yuan in 2005 to 643.15kWh / ten thousand yuan in 2016, with a decrease rate of 56.80%, which shows that energy efficiency in Hunan industrial development has greatly improved, and the energy-saving effect is obvious. The electricity consumption per unit output value of the primary industry and the tertiary industry are relatively flat.

Analysis of electricity consumption structure

According to the data, the secondary industry accounts for 57% of the total electricity consumption, reaching 84.773 billion kWh; residents and domestic electricity consumption is 38.718 billion kWh, accounting for 26% of the total. With the improvement of living standards, this proportion will be further enhanced; the tertiary industry electricity consumption is 24.259 billion kWh, accounting for 16% of the total; the primary industry electricity consumption is 1.816 billion kWh, accounting for only 1% of the total electricity consumption.

Analysis of Factors Affecting Electricity Consumption of Hunan Province. Based on the above analysis, changes of electricity consumption are closely related with economic development level, population and other factors. Therefore, the factors affecting electricity consumption (EC) analyzed in this paper include total GDP(GDP), population(RK), industrial structure(CYJG), residential consumption level(XF), urbanization level(CZH) and power consumption coefficient(XL). It is worth noting that, since the secondary industry accounts for a large proportion of the whole society's electricity consumption, the index of industrial structure is expressed as the ratio of the output value of the secondary industry to the total output value. Urbanization level is represented as the proportion of urban population to the total population; power consumption coefficient refers to the ratio of gross domestic product to electricity consumption.

The results of correlation analysis of electricity consumption and the six affecting factors are shown in table1.According to Table 1, the electricity consumption is positively related to the five factors of GDP, population, industrial structure, residential consumption level and urbanization level, which shows that these factors are main reasons for the rise in electricity consumption. Among them, the electricity consumption is highly related to GDP, residents' consumption level and urbanization level, significantly related to population and industrial structure, and negatively related to the power consumption coefficient.

Table 1 Correlation analysis results

	EC	GDP	RK	CYJG	XF	XZH	XF
EC	1.00						
GDP	0.96	1.00					
RK	0.79	0.68	1.00				
CYJG	0.72	0.54	0.88	1.00			
XF	0.91	0.98	0.54	0.38	1.00		
CZH	0.92	0.97	0.53	0.42	0.99	1.00	
XK	-0.87	-0.95	-0.66	-0.51	-0.92	-0.91	1.00

Electricity Consumption Forecast of Hunan Province

Multiple Linear Regression Model. Set the total GDP, population, industrial structure, residential consumption level, urbanization level and power consumption coefficient as independent variables and total electricity consumption as the dependent variable, the unit of each variable is shown in table 2.

Table 2 Variables and units

No.	variable name	unit	No.	variable name	unit
1	Total Electricity Consumption (YDL)	100 million kWh	5	residential consumption level (XF)	10 yuan
2	Total GDP(GDP)	Billion yuan	6	urbanization level (CZH)	%
3	Population(RK)	100 thousand	7	power consumption coefficient (XL)	kWh/yuan
4	Industrial Structure (CYJG)	%			

The multiple linear regression equation is established as follows:

$$YDL = \beta_0 + \beta_1 GDP + \beta_2 RK + \beta_3 CYJG + \beta_4 XL + \beta_5 CZH + \beta_6 XF \tag{1}$$

By taking use of Eviews 8.0, the coefficient of each variable can be calculated:

$$\begin{gathered} YDL = 713.62 + 0.55\,GDP + 1.67\,RK + 3.73\,CYJG - 105.97\,XL + 18.07\,CZH - 131.13\,XF \\ (473.34)\quad (0.04)\quad (0.37)\quad (2.83)\quad (14.02)\quad (2.96)\quad (10.28) \\ [1.50]\quad [15.64]\quad [4.46]\quad [1.32]\quad [-7.56]\quad [6.10]\quad [-12.76] \\ R^2 = 0.999858 \quad Adjusted\ R^2 = 0.999688 \quad D.W. = 2.399605 \end{gathered} \tag{2}$$

As can be seen from the results, the multiple linear regression model has a goodness of fit of more than 0.99. For the whole equation, the statistic F is 5883.029, and $p = 0.000000 < 0.05$ which is less than the given significance level. However, for the significance test of variables, both the constants and industrial structure fails to pass the test, and the coefficient of residential consumption level, which is negative, is contrary to expectation. Therefore, the model needs to be further tested and corrected.

By analyzing variance expansion factor, two independent variables, total GDP and residential consumption level are removed from the equation, and the multiple linear regression model is established as follows.

$$\begin{gathered} YDL = -6326.918 + 26.76\,CYJG + 55.61\,CZH + 4.87\,RK + 53.40\,XL \\ (876.15)\quad (8.71)\quad (4.97)\quad (1.39)\quad (53.40) \\ [-7.22]\quad [3.07]\quad [11.18]\quad [3.51]\quad [2.65] \\ R^2 = 0.992904 \quad Adjusted\ R^2 = 0.988850 \quad D.W. = 2.020451 \end{gathered} \tag{3}$$

From above equation, the constant is equal to -6326.918, indicating that a large amount of information has not been explained. Besides, for every 1% increase in the urbanization level, the electricity consumption will increase by 5.561 billion kWh. As for the power consumption coefficient, if it increased

by 1 kWh / Yuan, the electricity consumption will increased by 5.40 billion kWh.

The multiple linear regression model is used to predict the electricity consumption of Hunan Province in the next nine years. Supposing that the industrial structure remains unchanged in the next nine years, the urbanization level is in accordance with the goal proposed in the "13th Five-Year Plan" of Hunan Province that the urbanization level reaches 58% in 2020, the population increases with the growth rate of 6% and the power consumption rate declines by 7% each year, the forecast results are shown in Table 3.

Table 3 Electricity consumption forecast of Hunan Province

year	2020	2021	2022	2023	2024	2025
Electricity consumption[100 million kWh]	1747.55	1803.75	1861.77	1921.55	1983.04	2046.19

BP Neural Network Model. By the Matlab R2014 (a), the electricity consumption is forecasted using the functions provided by the neural network toolbox.

First of all, the training set and test set are generated randomly. There are 15 records as training and 5 records as test set.

Secondly, setting up and training the BP neural network, the minimum error of training target is 0.001, training times reaches 1000, and the learning rate is 0.01.

After the simulation test, the generalization ability of the network is evaluated by calculating the deviation between the predicted value and the true value. Evaluation indicators includes the relative error and determination coefficient.

In this paper, the results of BP neural network and RBF neural network are compared. The results indicates that the BP neural network algorithm has better forecasting performance and can meet the demand of decision-making.

The trained BP neural network is used for prediction, the result is shown in table 5.

Table 4 BP neural network prediction results

year	2020	2021	2022	2023	2024	2025
Electricity consumption[100 million kWh]	2046.66	2078.28	2108.27	2143.90	2173.41	2190.86

Combined Model. Based on the calculated results of 4.1 and 4.2, the optimal weights are obtained according to the Eq. 8, and the predicted results are obtained by Eq. 9, the results are shown in Table 5.

Table 5 Results of combined forecasting model

year	2020	2021	2022	2023	2024	2025
Electricity consumption[100 million kWh]	1971.88	2009.65	2046.64	2088.31	2125.82	2154.69

The mean absolute percent errors (MAPE) are calculated as shown in Table 6.

Table 6 Mean absolute percent error

No.	model	MAPE[%]
1	Multiple linear regression model	2．276
2	BP neural network model	9．010
3	Combined model	1.998

As can be seen from the table 8, the mean absolute percent error of the combined forecasting model among the three methods is the smallest, and mean absolute percent error of the BP neural network is the largest, which may be caused the small number of training samples; using the combined forecasting

model, the prediction accuracy increases slightly; we can draw the conclusion that multiple linear regression is an effective and simple method in this case.

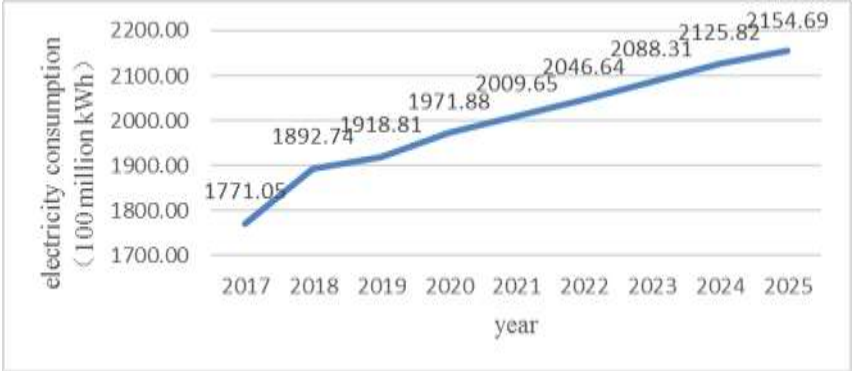

Figure 1. Combined forecasting model prediction results

From Fig. 1, the electricity consumption in Hunan Province shows an increasing trend in the next nine years. According to the results of the combined forecast model, the electricity consumption will reach 19771.88 billion kWh by 2020, and it will reach 215.469 billion kWh by 2025 with an average growth rate of 2%. Compared with the previous ten years, the growth rate of electricity consumption in Hunan in the next nine years is relatively lower, which is related to the of industrial structure adjustment and the declining economic growth of Hunan Province.

Summary

Based on the analysis of factors affecting electricity consumption in Hunan Province, in this paper, we predicts the electricity consumption using multiple linear regression model, BP neural network model and combined forecasting method respectively of Hunan Province. The results show that the forecasting accuracy of combined forecasting model is higher than that of single forecasting models, but the improvement is slight. According to the results, compared with the previous ten years, the growth rate of electricity consumption in Hunan Province in the near future will be at a low level, which is related to the industrial structure adjustment and the declining economic growth of Hunan Province.

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