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The electric power demand forecasting in China based on the Generalized Regression Neural Network (GRNN)

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Abstract: With the rapid development of economy, the electric power consumption increases year by year in China. Therefore, power demand forecasting plays an important role in ensuring the power supply. According to the effect factors about the power demand in China, we established the electric power demand forecasting index system, which applied the generalized regression neural network principle. After training the network by using the 1996-2010 years' data, we made a forecast about the power demand during the China's new Plane. According to the forecast results, it shows that the power demand is still in the further growth during the China's new Plane, but the growth rate has dropped. Besides, it puts forward some suggestions to meet the power demand for the development in economic society.

Keywords*:* generalized regression neural network, Demand, forecast

1. Introduction

In the present-day world most of the economic is energy economy, which is based on the power. Electric power is the foundation industry in the national economy. The rapid and stable development of any industries cannot be without the adequate supplies of electricity. The electric is in short supply for a long-term in our country. Especially in recent years with the rapid development and the quickening process in industrialization and urbanization, the electric power imbalance between supply and demand has gradually become the main influence factors to the further development of economic social. Since 2002, the electric power gap is large in 12 provinces of our country. Later there are more and more provinces beginning to lack in electricity. Many provinces have to limit electricity in the summer. The power imbalance between supply and demand has gradually increased. According to the economic development planning, the economic growth will continue to maintain the 8% growth rate in the future twenty years. The industrial construction needs a strong support of electricity supply. The power supply was not only impacted by resources endowment, level of economic development and average living standard, but also impacted by the electric power demand forecasting. The forecasting about conservative electric power demand will lead to the electricity in short supply and affect the normal production and living order. So the power demand forecasting must be scientific, effective, and accurate, and should select the factors that can impact the power demand. Besides, it should establish the scientific and reasonable index system according to the market economy form. This paper used Generalized Regression Neural Network to forecast the power demand during China's new Plane, which is based on establishing the index system. Through forecasting the electric power demand in our country we can be timely and accurate to grasp the changes in electric power supply and demand of our country, dissolve the possible crisis and improve the stability and safety in power supply. At the same time it can provide decision support to ensure the healthy and stable development of China's economic social.

The research in electric power demand forecasting began in the western developed countries in 1980's. It mainly uses the General Exponential Smoothing Method, Regression Method, the Autoregressive Moving Average Method, Moving Average Method and Artificial Intelligence Method [1]. Our country also attaches great importance to electric power demand forecasting research. And it mainly use Multiple Linear Regression, ARMA, GM - ARMA, BP Neural Network, Particle Swarm Optimization BP Neural Network and Support Vector Machine (SVM) and Least Squares Support Vector Machine (SVM), the Gray System Theory, the Grey Markov Chain Model, and the Electrical Elasticity Coefficient Method, etc. Neural Network and Grey Model are used most. The Generalized Regression Neural Network (GRNN for short) has high fault tolerance and nonlinear mapping ability, and it is very suitable for solving nonlinear problem. Comparing with the Radial

Basis Function Neural Network (RBF for short) , GRNN has more advantages in approximation ability and learning speed. Besides, if there is few sample data, the GRNN prediction is better than the BP neural network [2]. This paper uses Generalized Regression Neural Network to forecast the power demand in our country.

2. The basic overview about the Generalized Regression Neural Network

The Generalized Regression Neural Network (GRNN for short) is a kind of Ratio Basic Function Neural Network (RBF for short).It was proposed by Donald F. Specht, an American scholar, in 1991.

2.1. The basic theory of generalized regression neural network

GRNN is based on the theory of nonlinear regression. The Nonlinear Regression about dependent variable Y relative to the independent variable X is the biggest estimate value of random variable y relative to the random variable x. Now consider the function $f(x,y)$ is the joint probability density function about the random variable x and y. And x is the observation value, a known quantity, then the nonlinear regression of random variable y is:

$$\hat{Y} = E(\mathrm{y}|X) = \frac{\int_{-\infty}^{\infty} y f(X,y) d_y}{\int_{-\infty}^{\infty} f(X,y) d_y} \quad (1)$$

In equation (1), if we input variable x, $\hat{Y}$ is the estimation output.

The sample data set $\{x_i, y_i\} i = 1,2,3...n$ use the non-parameter estimation, and we can get the estimate density function $\hat{f}(X,y)$.

$$\hat{f}(X,y) = \frac{1}{n(2\pi)^{\frac{p+1}{2}} \sigma^{p+1}} \sum_{i=1}^{n} \exp\left[-\frac{(X-X_i)^T (X-X_i)}{2\sigma^2}\right] \exp\left[-\frac{(X-Y_i)^2}{2\sigma^2}\right] \quad (2)$$

In equation (2), X_i and Y_i is the sample observation values of random variables x, y; n is the samples; p is the dimension of random variable x; σ is the width coefficient of the Gaussian function.

In equation (1), we replace $f(X,y)$ for $\hat{f}(X,y)$ and exchange the order of integral and add, so we can get the following equation:

$$\hat{Y}(X) = \frac{\sum_{i=1}^{n} \exp\left[-\frac{(X-X_i)^T (X-X_i)}{2\sigma^2}\right] \int_{-\infty}^{\infty} \exp\left[-\frac{(Y-Y_i)^2}{2\sigma^2}\right] d_y}{\sum_{i=1}^{n} \exp\left[-\frac{(X-X_i)^T (X-X_i)}{2\sigma^2}\right] \int_{-\infty}^{\infty} \exp\left[-\frac{(Y-Y_i)^2}{2\sigma^2}\right] d_y} \quad (3)$$

Because of $\int_{-\infty}^{\infty} ze^{-z^2} dz = 0$, we can get the output of the network $\hat{Y}(X)$ after calculating the two integrals in equation (3):

$$\hat{Y}(X) = \frac{\sum_{i=1}^{n} Y_i \exp\left[-\frac{(X-X_i)^T (X-X_i)}{2\sigma^2}\right]}{\sum_{i=1}^{n} \exp\left[-\frac{(X-X_i)^T (X-X_i)}{2\sigma^2}\right]} \quad (4)$$

The weight of each observation Y_i is the index of the corresponding sample observations X_i and the Euclidean distance square between X. We can get the averaging estimate values $\hat{Y}(X)$ by weighting average the sample observations Y_i. Only when the value of smooth factor σ is moderato, the generalization ability of network is better, and the prediction effect is also better [3].

2.2. The network structure of Generalized Regression Neural Network

GRNN network and RBF network are pretty similar in the network structure. The structure of the GRNN is composed by input layer, Pattern layer, summation layer and output layer. As shown in figure 1.

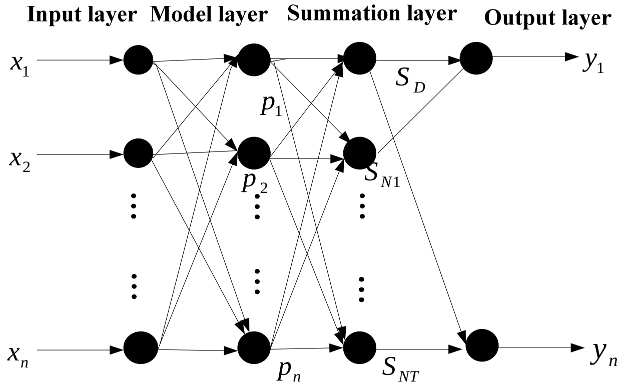

Figure 1. The network structure of Generalized Regression Neural Network

(1) input layer

The number of neurons in GRNN input layer is equal to the dimension of the input vector in training samples. Each neuron does not do the function calculation, but directly pass the input vector to the neurons of next layer.

(2) pattern layer

The number of neurons in GRNN Pattern layer is equal to the training samples. The neuron transfer function of Pattern layer is as follows:

$$\mathrm{p_i} = \exp\left[-\frac{(\mathrm{X}-\mathrm{X_i})^T (X - X_i)}{2\sigma^2}\right] ....i = 1, 2, ...n \qquad (5)$$

In equation (5), X_i is the sample observation values about the corresponding ith neuron.

(3) summation layer

In GRNN summation layer we use two functions.
A calculation formula is:

$$\sum_{\mathrm{i}=1}^{\mathrm{n}} \exp\left[-\frac{(\mathrm{X}-\mathrm{X_i})^T (X - X_i)}{2\sigma^2}\right] \qquad (6)$$

In equation (6) we calculate the sum of neurons output in the model layer. The connection weight value is 1 of each neuron in model layer and summation layer. The transfer function is:

$$S_D = \sum_{\mathrm{i}=1}^{\mathrm{n}} P_{\mathrm{i}} \qquad (7)$$

Another type of calculation formula is:

$$\sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{Y_i} \exp\left[-\frac{(\mathrm{X}-\mathrm{X_i})^T (X - X_i)}{2\sigma^2}\right] \qquad (8)$$

In equation (8), we weighted summation about the output of all neurons in the model layer. The link weight between jth neuron in summation layer and the ith neuron in pattern layer is the jth output element of the ith output sample. The transfer function is as the following:

$$S_{N\mathrm{j}} = \sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{y_{ij}} P_{\mathrm{i}} \text{。} \quad \mathrm{j} = 1, 2,, ...k \qquad (9)$$

(4) the output layer

The number of neurons in GRNN output layer is equal to the training sample output vector dimension, namely:

$$\mathrm{y_j} = \frac{S_{N\mathrm{j}}}{S_D} ....\mathrm{j} = 1, 2, ...k \qquad (10)$$

2.3. The function of Generalized Regression Neural Network

The function name of Generalized Regression Neural Network in Matlab is newgmn().This function is used to establish a Generalized Regression Neural Network to function approximation. The call format is $\mathrm{net} = \mathrm{newgrnn}(P, T, spread)$: Among them, the P is a R * Q d matrix which is composed by input vectors . Namely, it is the transposed matrix of the input vector group; And T is S * Q d matrix which is composed by target classification vectors. And the S * Q d matrix is the transposed matrix of output vector group; Spread is the expansion speed of Radial Basis Function, and the default value is 1.

3. The forecasting in electric power demand of our country

3.1. The influence factors of power demand in our country

There are many factors influencing the electric power demand in our country, but it mainly has the following several factors:

(1) Gross Domestic Product (GDP)

Because the development of economy has a large dependence on electricity power, Gross Domestic Product (GDP) is the basic factor to power demand. The Guofang Mi and ZhaoTao use VAR model, Johansen multivariate co-integration test and Granger Causality analyses the relationship between economic growth and power consumption. The results show that there is long-term stable co-integration relationship between them, and the two are mutually interdependent about the Granger Causality [4]. SongXiaoHua believes that the change in GDP change and the power consumption changes have the positive correlation relationship, always increasing or reducing at the same time [5]. WangYuJi also proves the stable significantly positive correlation between GDP growth and the power consumption [6-7].

(2) The industrial structure

In the three industries structure, the second industry has a large proportion. Power consumption is far more than the other industries, accounting for the large proportion of social power consumption. Along with the adjustment of industrial structure, the power consumption proportion of third industry in three industries will be larger and larger. The power consumption will also increased. The power consumption proportion of second industry would be decreased. so the structure adjustment of the three industries will also affect the change of power demand[8-10].

(3) Population

The population is an important factor in influencing the power demand. First of all, the growth of the population will lead to the growth in power demand. The population base is bigger in our country, so the growth of the population brings the demand in material goods, leading to the demand in power. At the same time, the quality and the structure of the population can also affect the power demand in our country. Although China's population growth rate has been lessened by using the family planning, the power demand has increased persistently. The population growth rate and the power consumption had a negative correlation relationship. Second is the improvement of people's living standard, which leads to the growth in power demand.

(4) Resident income

Since the reform and openness, people's living standard is increasing day by day. In recent years, the power consumption in residents has increased rapidly. The income level of residents directly impacts the electricity consumption in residents. Generally speaking, the high income level family will have more Household Appliances, so the power consumption is also relative high. It has the certain positive correlation between the power consumption and income.

3.2. The designing of the index system

Choosing the effective index to construct the electric power demand forecasting index system is the key for obtaining the scientific prediction effect. There are numerous lays, complicated structure in the internal of power demand system. Each subsystem is interaction and influenced each other. So if we want to construct a scientific and effective evaluation system, we must follow the following principles:

(1) the scientific principle: There are many factors that affect the electric power demand . And the factors are closed to each other. So the factors we choosed should be able to fully and objectively to show the influence factors of the power demand.
(2) operational principle: It mainly refers to the index data ,used for evaluating, must be able to get through the national or local statistical yearbook and the energy statistical yearbook. Besides, we also should use the uniform diameter consistent data. In addition, the standardization of data can ensure the contrast analysis of the selection data.
(3) Simplicity principle: The aspects of electric power demand forecasting involved is very wide. If we reach every aspect of it we can construct many indicators, and increased the difficulty in the specific operating. Therefore, during the Settings of the index system we must choose some representative composite indicator. So we can use the few indicators to reflect the key factors in the electric power demand.
(4) dynamic principle: The changes in electric power demand is a dynamic process. The index system need different strategies index to amend and replenish ,which can agilely revealed the dynamic change process in power demand.

This article satisfied the above principles when it selected the index system. We selected the indicators and establish the indicator system according to the influence factors in the power demand. Also, considering the operability and availability of the index system, we further screen the index system, and finally we form the evaluating index system. So this paper selected GDP, the tertiary industry output value, population, per capita disposable income of residents' family of urban, pure income of farmer family five indicators to establish the indicator system. The annual power usage, GDP, the tertiary industry output value, population, per capita disposable income of resident' s family of urban, pure income of farmer in 1996-2010 are shown in table 1.

Table 1. Index data

year	*Electric power demand (KWH)*	*GDP (hundred million)*	*The tertiary industry output value(hundred million)*	*population (Ten thousand people)*	*per capita disposable income of resident' s family of urban(yuan)*	*pure income of farmer family(yuan)*
1996	10764.3	71176.59165	23326.24	122389	4838.9	1926.1
1997	11284.4	78973.035	26988.15	123626	5160.3	2090.1
1998	11598.4	84402.27977	30580.47	124761	5425.1	2162
1999	12305.21	89677.05475	33873.44	125786	5854.02	2210.3
2000	13472.4	99214.55431	38713.95	126743	6280	2253.4
2001	14633.5	109655.1706	44361.61	127627	6859.6	2366.4
2002	16331.5	120332.6893	49898.9	128453	7702.8	2475.6
2003	19031.6	135822.7561	56004.73	129227	8472.2	2622.2
2004	21971.4	159878.3379	64561.29	129988	9421.6	2936.4
2005	24940.3	184937.369	74919.28	130756	10493	3254.9
2006	28588	216314.4259	88554.88	131448	11759.5	3587
2007	32711.8	265810.3058	111351.9	132129	13785.8	4140.4
2008	34541.4	314045.4271	131340	132802	15780.76	4760.62
2009	37032.2	340902.8126	148038	133450	17174.65	5153.17
2010	41900	401202.0284	173087	134091	19109.44	5919.01

The trend diagram of GDP and the tertiary industry output value are shown in figure 2 during 1996-2010.The population of our country are shown in figure 3 during 1996-2010. The per capita disposable income of residents' family of urban, pure income of farmer is shown in figure 4 during 1996-2010. The electric power demand is shown in figure 5 during 1996-2010.

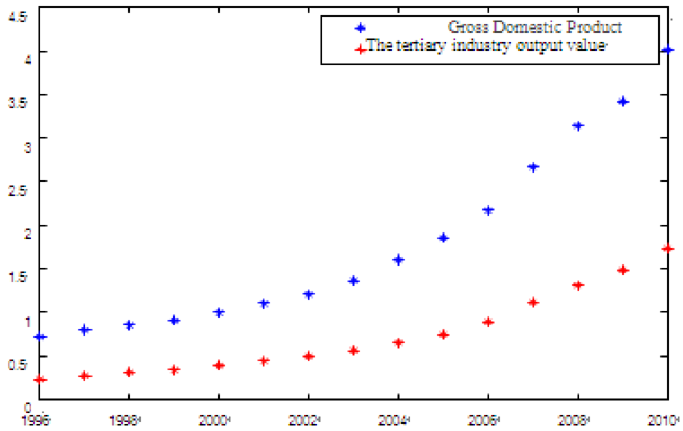

Figure 2. The trend diagram of GDP and the tertiary industry output value during 1996-2010

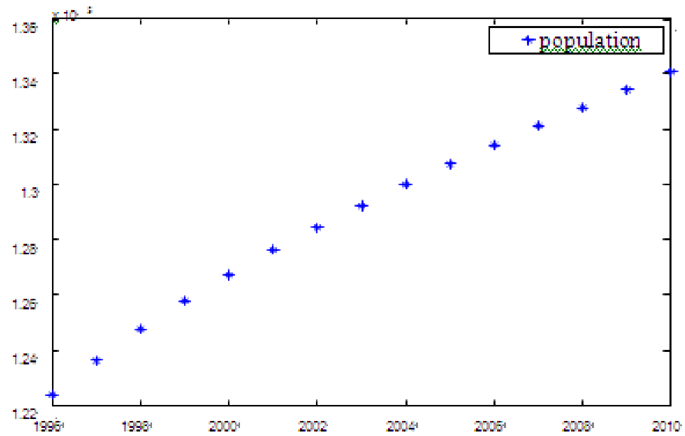

Figure 3. The population of our country during 1996-2010

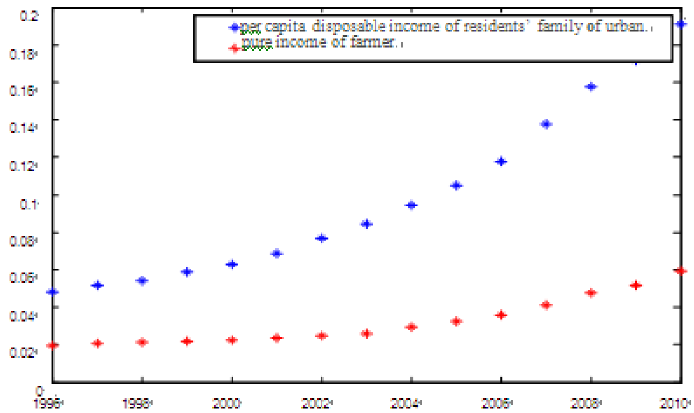

Figure 4. The per capita disposable income of resident' s family of urban and pure income of farmer during 1996-2010

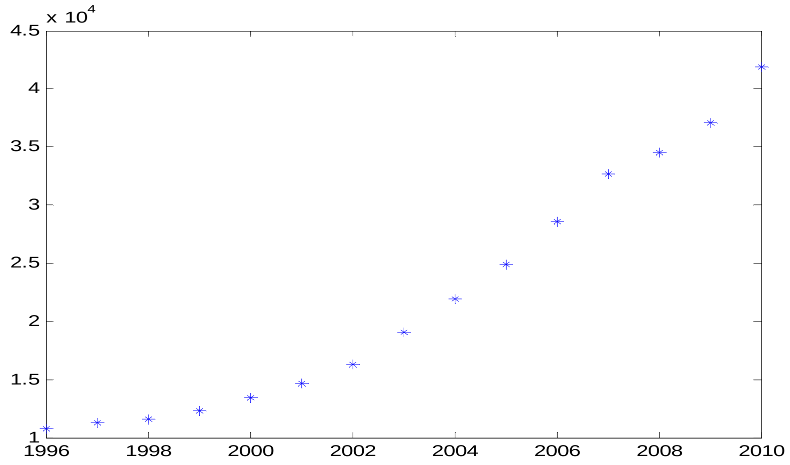

Figure 5. The electric power demand during 1996-2010

3.3. Model and forecasting

This paper selected GDP, the tertiary industry output value, population, per capita disposable income of resident's family of urban, pure income of farmer family during the 1996 to 2010, as the input of Generalized Regression Neural Network, and the power consumption in 1996-2010 as output of Generalized Regression Neural Network. Besides, this paper establishes the Generalized Regression Neural Network, using matlab9.0 to do the procedures simulation analysis. According to the China statistical yearbook data it use the 1996-2010 years' data as the network training sample to train the network. There is only one optimize parameters by using Generalized Regression Neural Network to forecast. After the repeated verification we can get that sperad is equal to 0.8. The error between power demand predicted value and the real minimum is minimum, and the fitting is good. When the Spread is equal to 0.8,the power demand simulation prediction fitting curve are shown in figure 5 and 6:

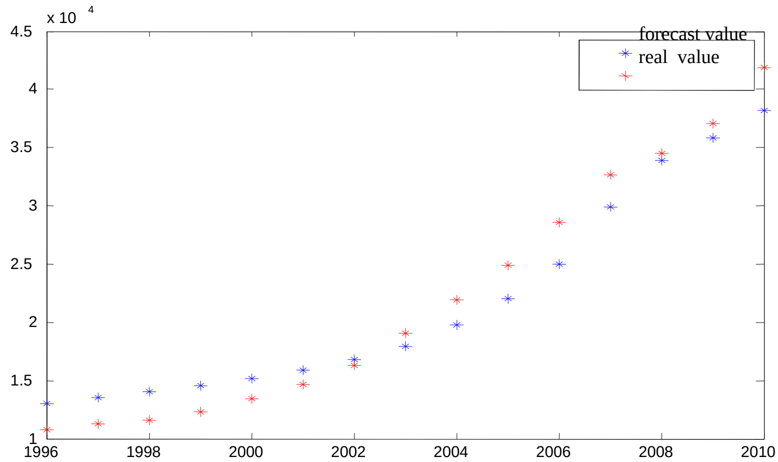

Figure 6. The empirical analysis shows :There is only one parameters to optimize

Through using Generalized Regression Neural Network to predict the power demand error is very small. And it overcomes the shortcomings in BP neural network and support vector machine (SVM) that need a large number of samples to train, more parameters to optimize. It is a kind of good forecasting model of electric power demand. So we can use Generalized Regression Neural Network to forecast the power demand in China, put the China's new Plan index data as the input of the network and call sim function to do the simulation prediction about the China's new Plan index data. The prediction results are shown in table 2.

Table 2. The forecasting of electric power demand in our country

year	***2011***	***2012***	***2013***	***2014***	***2015***
Predict value	45574	49571	53918	58647	63791

4. Conclusion

Through the above forecasting results we can see that in the future five years the electric power demand in our country will increase persistently . In 2015, the power consumption will pass 6.3 trillion kwh. The average annual growth rate of social power consumption will be 8.7%. The average annual growth rate is lower than the 11th five-year in which growth rate is 9.31%. The energy saving and emission reduction made a principium success. So during the China’s new planning, we must further implement the China’s new planning and environmental planning, further advocate low carbon economy and improve people's low carbon energy saving consciousness and slow down the conflict in electric power supply and demand. At the same time we should make the reasonable price, complete the electric power planning and forecasting work and ensure the stability and healthy development of the economic social in the our country.

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