Prediction of Industrial Electric Energy Consumption in Anhui Province Based on GA-BP Neural Network

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Abstract. In order to improve the prediction accuracy of industrial electrical energy consumption, a prediction model of industrial electrical energy consumption was proposed based on genetic algorithm and neural network. The model use genetic algorithm to optimize the weights and thresholds of BP neural network , and the model is used to predict the energy consumption of industrial power in Anhui Province, to improve the prediction accuracy of industrial electric energy consumption in Anhui province. By comparing experiment of GA-BP prediction model and BP neural network model, the GA-BP model is more accurate with smaller number of neurons in the hidden layer.

1. Introduction

Industry is the leading industry of the national economy, and the industrial electric energy consumption is the main part of electric power of the whole society. The study of industrial electricity consumption can not only fully support the local industrial development, but also rational use electrical energy and conserve energy. At present, the use of statistical algorithm, engineering technology and experience explore the relationship and variation law between the electric load and the local economic situation to forecast the future electricity load by the analysis and research of electric load historical data. Anhui industrial electric load accounts for more than 60% of the province's electricity load. The study of the relationship between the economic situation and the electricity load has important significance for the rational use of electricity and power saving in Anhui province.

Previous scholars' research mainly focused on the prediction of the electric power of the whole society and residential electricity consumption. For example, Zhou Qi [1] studies the whole society electricity consumption forecasting method based on macroeconomic indicators; Jianchao Li [2] uses neural network to predict the change of electricity consumption in the national electricity consumption. However, industrial electricity consumption is less and most of the prediction methods are not optimized. Yiliang Wu [3] studied the model of predict the electricity quantity based on support vector machine with the monthly total target statistics value of Guangdong power grid on electricity consumption of large industrial customers , using LIBSVM software to predict practically and validate and analyse. In

the studies, the influence of the facts of GDP, the total output value above scale, the total investment of fixed assets and the amount of import-export volume on the electricity consumption is emphatically considered, and an effective short-term forecasting method of electricity consumption is established. According to the characteristics of daily load change of industrial boiler room, Lan Peng [4] use BP artificial neural network model to predict the thermal load. However, the parameters of these methods are difficult to optimize, are set all by experience, and the prediction accuracy is not high.

BP neural network is widely used in various fields of predicting complicated problems, but the BP neural network model need to provide a lot of weight and threshold parameters, it is difficult to give better values for these parameters, given by random or empirical generally. Genetic algorithm (GA) follows the principle of "survival of the fittest", selects the individuals with good evolution as the optimal solution, it can provide better parameters for the BP neural network. The GA algorithm is often applied to the parameter tuning of BP, this is called GA-BP neural network.

The contributions of this paper are as follows: first, GA algorithm is used to optimize the parameters of BP neural network to improve the prediction accuracy and accuracy; second, GA-BP is used to predict the energy consumption of industrial electricity in Anhui. Third, the predictions accuracy of GA-BP neural network and BP neural network are compared in industrial power consumption of Anhui province by the Mat lab experiment.

2. BP neural network and improvement

2.1. BP neural network structure and principle

BP neural network is the most widely used neural network at present. The special thing is that its transfer function of BP neurons is nonlinear. The known learning samples are input into the neural network with set structure, the weight and threshold of the previous iteration, and the output of each neuron is calculated from the first layer in turn back, Then, the influence of each weight and threshold on the total error is calculated from the last layer in turn forward. So the weights and thresholds are modified until convergence [5]. The topology structure of the BP neural network is shown in figure 1.

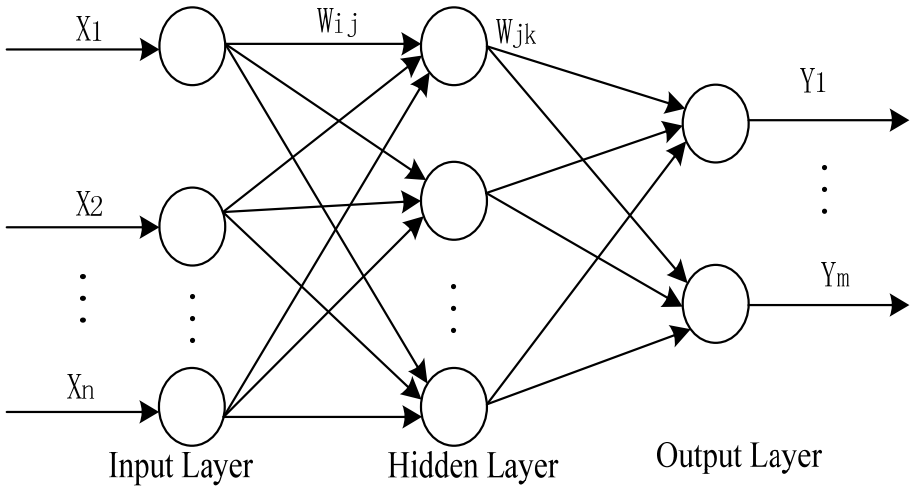

Figure1. The topological structure of BP neural network.

In Figure 1, X_1, X_2... X_n are the input value of the neural network; Y_1, Y_2... Y_n are the output value of BP neural network, and W_{ij} and W_{jk} are weights of neural network. The weights and thresholds of BP neural network can be trained by BP neural network. First, the weights and thresholds of the BP neural network in each layer are randomly assigned to any value between [0, 1].Then the BP neural network is trained.

2.2. The deficiency and improvement of BP algorithm

Although the BP neural network can realize complex nonlinear mapping, it has a strong self-learning ability and is suitable for solving complex problems of internal mechanism. But BP neural network is an algorithm based on gradient descent method, and the convergence speed is usually slower [6]. BP neural network is a local search optimization algorithm, which may fall into local extremism and make training fail.

Genetic algorithm is a global search optimization algorithm based on genetics. Starting from the initial population, genetic algorithm simulates a kind of biological phenomenon about reproduction, mating and variation. And then it can produce a new group of more adaptable environment [7].The main idea of the algorithm: Firstly, the actual problem is transformed into the objective function, and then the objective function is mapped to the fitness function. An initial population is randomly generated to calculate the fitness value of each chromosome. Then the individuals of the highest chromosomal fitness are selected for genetic operation, and then a more adaptive environment individual is generated after the operation of crossover and mutation. Thus, there are iterative evolutions between generations and generations, until one of the most adaptable individuals is generated to solve the problem.

Aiming at the shortcoming of BP neural network that the convergence speed is slow and the randomly initial weights and thresholds lead it to fall into local optimum eastily, in this paper, we use the genetic algorithm of global search and optimization to improve the accuracy of the BP neural network by optimizing its initial weights and thresholds.

3. The model of GA-BP neural network

The prediction model of industrial electric consumption of Anhui province is constructed to more accurately predict the industrial electric consumption by the GA-BP neural network. The structure of GA-BP neural network is shown in Figure 2.

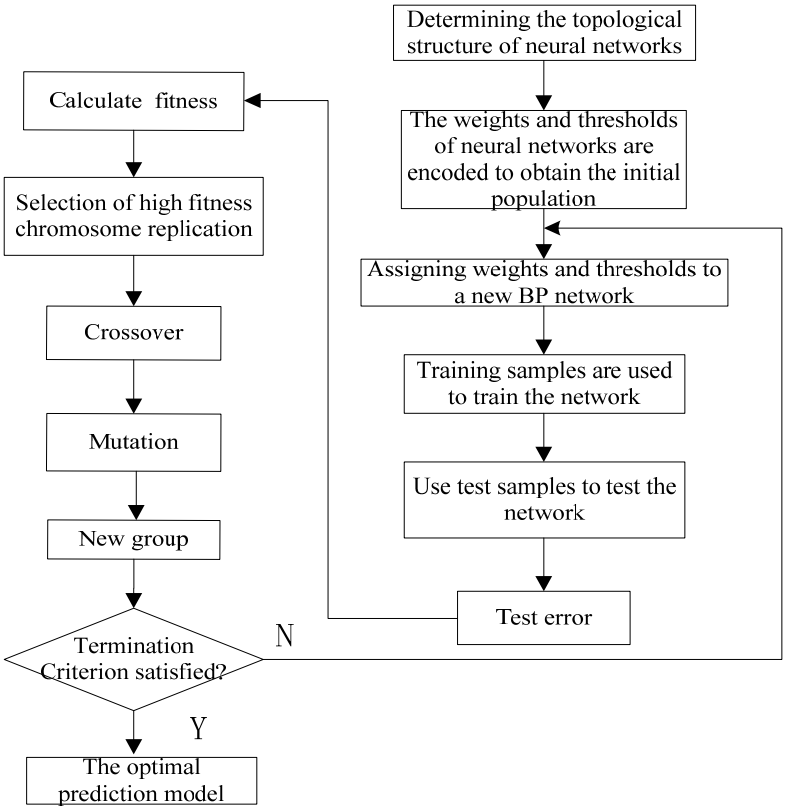

Figure 2. GA-BP neural network prediction structure flow chart.

3.1. Determination of the structure of neural network model

The BP neural network in the industrial electric energy consumption prediction model of Anhui province adopts the classical three-layer structure. The number of neurons in the input layer is R, and the R is equal to 5 according to the actual situation. The number of hidden neurons is S_1, and S_1 is set to 2R+1 according to the experience; then by the many experiments, finally it will be set an optimal value. The number of output layer neurons is S_2, and the S_2 is equal 1 to represent the industrial electric energy consumption. W_1, the connection weights of input layer and hidden layer, is the matrix of $R*S_1$; W_2, the connection weights of output layer and the hidden, is the matrix of S_1*S_2; B_1, the hidden layer threshold, is the length of the vector S_1; B_2, the output layer threshold, is the length of the vector S_2.

3.2. Genetic algorithm to optimize the weights and thresholds of BP neural network

(1) Initial population

The predictive model of industrial electric energy consumption in Anhui province is coded in real numbers. The coding string consists of four parts: W_1, the connection weights input layer and hidden layer; W_2, the connection weights of output layer and the hidden layer; B_1, the threshold of hidden layer; B_2, the threshold of the output layer. S, the encoding length is equal to $R*S_1+S_1*S_2+S_1+S_2$.

The initial encoding is an increasing number of real numbers starting from 1. Among them,

$$W_1(i, k) = R*(i-1) + k,\ i \in [1,S_1],\ k \in [1,R]; \tag{1}$$

$$W_2(i, k) = S1*(i-1) + k + R*S_1,\ i \in [1,S_2],\ k \in [1,S_1]; \tag{2}$$

$$B_1(i, 1) = R*S_1+S_1*S_2+i,\ i \in [1,S_1]; \tag{3}$$

$$B_2(i, 1) = R*S_1+S_1*S_2+S_1+i,\ i \in [1,S_2]; \tag{4}$$

W_2 is progressive increased basis on W_1; B_1 is progressive increased basis on W_2; B_2 is progressive increased basis on B_1.They are connected together to form a long string and constitute a complete chromosome. In the range of connection weights and thresholds, the M chromosomes form the initial population. The encoding structure is shown in Figure 3.

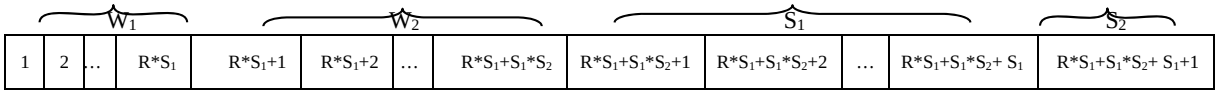

Figure 3. Initial encoding

(2) Fitness function

After the initial encoding is obtained, the initial coding is assigned to the neural network. The optimal weights and thresholds are obtained by training data, thus the neural network model is obtained. The square error of predictive value and the true value is called SE. Fitness function value val=1/SE .The genetic and mutation operations in the algorithm are based on the fitness value. Individuals with higher fitness are more likely to inherit into the next generation, while individuals with lower fitness are less likely to inherit into the next generation.

(3) Genetic operation

The operation of selection adopts the method of sorting selection. According to the size of each individual fitness value, they are arranged from small to large. The minimum fitness value corresponds to the number 1 and the maximum fitness value corresponds to the number M. Then the probability of individual selection is calculated by the selection method of the fitness ratio.

After selecting the operation, the crossover operation is performed by single point crossover, two chromosomes are selected randomly by the selected groups, and a point is selected randomly to exchange the values on the point of two chromosomes. Then, after the crossover operation, the mutation

was performed with uniform variation, the random number of the uniform distribution was used to select the loci to be mutated in the coding string, and the gene value of the locus was replaced by a smaller probability-P_m.

A new population is obtained, by the selection, crossover and variation. Firstly, the population is used as the initial weight and threshold of BP neural network; secondly, the optimal weights and thresholds are obtained by training data, and then the neural network model is obtained. The fitness value of each chromosome in the current population is calculated by the test data. The selection, crossover and mutation are repeated according to the fitness value, until the test error of the model is less than the specified value or the specified maximum genetic iterations is reached.

(4) The optimal GA-BP neural network

After the genetic iteration cycle is terminated, the model with the higher fitness value is selected from the model trained by the individual of the last generation population. That is, the model with small test error is taken as the forecast model of industrial electric energy consumption in Anhui province.

4. Experimental analysis

In this paper, the model is designed and implemented by Mat lab, and forecast Anhui industrial electric energy consumption base on the data of Anhui industrial electric energy consumption. The BP neural network and GA-BP neural network models with four different neurons in hidden layers of the topological structure of are trained and tested 20 times, the four different neuron amounts are 4, 7, 11 and 15 (S_1=4,S_1=7,S_1=11 and S_1=15) respectively. Then the test result and the result of testing BP neural network are compared and analyzed.

4.1. Sample Date

According to the importance of industrial-related economic indicators on industrial electric power consumption, the monthly added value of high-tech industry, large and medium industries, industry, strategic emerging industries and the leading industry as input data, the monthly industrial electric consumption as the output data, the input data and output data are from the monthly data of the Bureau of Statistics of Anhui province between May 2003 and April 2017 .The model of GA-BP and BP are trained and tested on this data. Among 80% randomly selected data as the training sample, and the remaining 20% data as test samples. These data are listed in Table 1 (added value unit: million, industrial electric consumption unit: kWh).

Table 1. Industrial added value and electricity consumption value of Anhui in 2012 -2017.

Time	The added value of high tech industry	The added value of large and medium industries	The added value of industry	The added value of strategic emerging industries	The added value of the leading industry	The value of industrial energy consumption
2012.6	178.75	337.97	579.86	396.60	380.04	780093
2012.7	191.71	333.69	597.15	401.60	387.67	1008423
2012.8	205.58	335.20	608.27	405.60	393.75	833350
…	…	…	…	…	…	…
2017.3	412.60	537.60	1007.20	1117.70	805.02	988340
2017.4	383.80	496.30	958.70	1000.29	757.70	933506

4.2. Experimental Results

Through the above experiments, we get the following results under the topological structures:

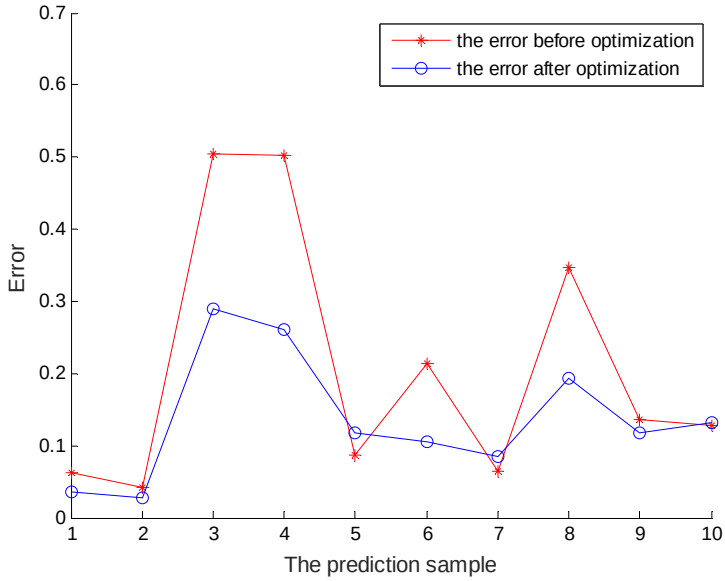

Figure 4.S1=4 Errors Comparison.

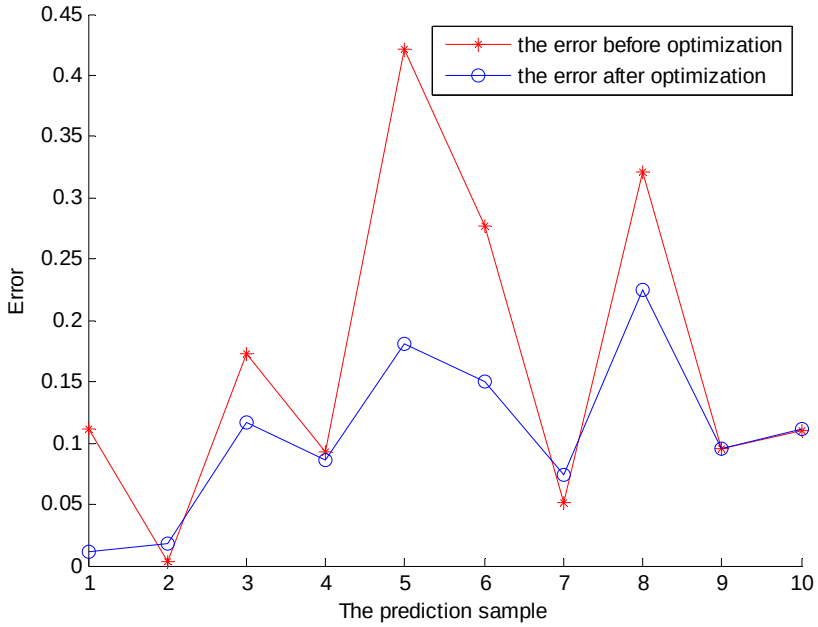

Figure 5. S1=7 Errors Comparison.

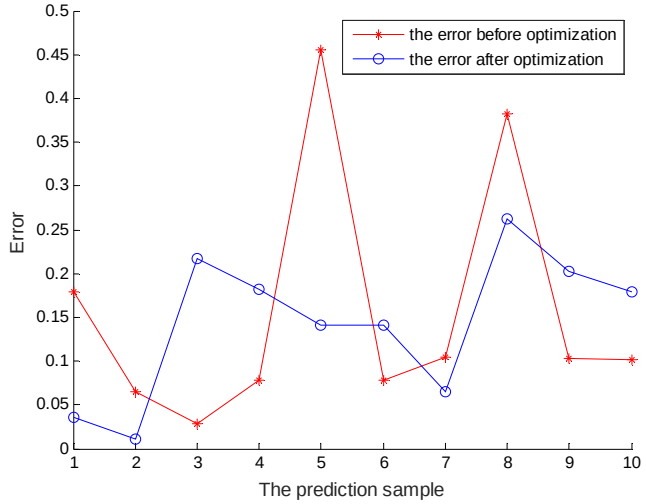

Figure 6.S1=11 Errors Comparison

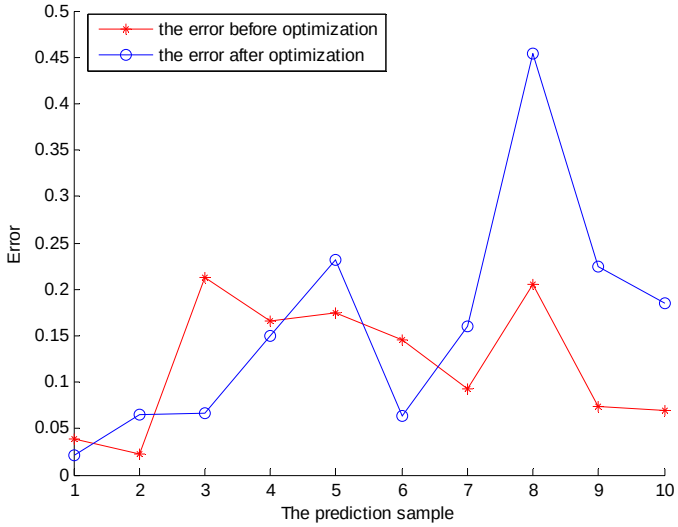

Figure 7. S1=15 Errors Comparison

In Figure 4, the number of neurons in the hidden layer is equal to 4. The red line represents the error of BP neural network prediction, and the blue line represents the error prediction of GA-BP neural network. The prediction error of the neural network after optimization is smaller and the error fluctuation is smaller than before optimization.

In Figure 5, the number of neurons in the hidden layer is equal to 7. The error and fluctuation of the prediction after optimization are larger than before optimization. The average error after optimization is larger than that of S_1=4, but its error fluctuation is smaller than that of S_1=4.

In Figure 6, the number of neurons in the hidden layer is equal to 11.After optimization, the error fluctuation is smaller than before optimization. But the average error of the optimized prediction is larger and error fluctuation is larger than that of S_1=4 and S_1=7.

In Figure 7, the number of neurons in the hidden layer is equal to 15.It is shown from the diagram that the optimization effect is worse than before optimization, and the error and error fluctuation is larger

than before optimization. The number of hidden layer neurons has a great influence on the optimization effect.

5. Conclusion

Compared with the BP neural network, the optimized BP neural network by genetic algorithm can effectively avoid the training into the local minimum point, thus lead to greater error fluctuations. In this paper, the model of the electric energy consumption forecast of Anhui province of GA-BP Neural Network has good simulation performance and has high prediction accuracy with smaller number of neurons in the hidden layer. The number of neurons in the hidden layer of neural network has a great influence on the prediction of GA-BP neural network. The GA-BP model is helpful to obtain more accurate prediction result, so that the relevant departments can reasonably plan the use of electricity and distribution, and promote the development of industrial economy in Anhui province.

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