

The study on energy demand forecast of Chongqing^{*}

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Abstract: Energy demand forecasting is the base for programming energy system. With the economy development, the increasing amount of energy consumption is in contradiction with the exhausted resource and destroyed environment. For the sake of the sustainable development, the reasonable energy demand forecasting is needed, and it is the scientific reference for establishing energy developing stratagem and energy policy. But the traditional forecasting methods at present have some limitations. Artificial neural network(ANN) is a new and developing subject, whose capability of adaptability and self-study is excellent. Based on the analysis as above, the forecasting model with artificial neural network was established. This model is based on the idea of time series. Compared with the traditional algorithm, this model is more friendly and maneuverability, which is not only able to forecast for a short term, but also able to forecast for a long period. Based on the fact of Chongqing, the energy demand of Chongqing is analyzed, and then it is forecasted from 2002 to 2020 with the model, and the forecasting results are reasonable.

Keywords: energy demand; forecast; ANN

1. Introduction

Energy is the important basis for the living of people and improvement of society. For the modern construction of Chongqing in the future, the exploitation and construction, reasonable distribution and the effectively utilization of the energy are the key factors. When analyzing the environment influence with the economy development in the future, the energy demand is needed to forecast. The long investment period and the great amount of money for the investment are the two important characters of energy industry. Energy system is a big inertia system for its several years even more investment period, it changes long after the varying of energy demand at any moment. It is difficult that the market adjusts itself to balance the energy supply and energy demand. When the energy supply is insufficiency or overstock, it may bring great loss to economy, so the energy supply should be studied deeply, and a reasonable energy forecast in the future should be given, which could give a scientific reference for energy development stratagem or energy policy, and make the national economy develop well at a proper rate.

But the traditional forecast technique at present does not accord with its importance, and it has some limitation: almost all the methods are based on the traditional methods, such as trend extrapolate, probability statistics, investigation analysis. There is

short of new method with favorable performance. Although some new methods such as gray forecast, decision-making system, have been adopted, they have some limitations also. Fortunately, the artificial neural network developed quickly gives us a good choice. The ANN models depend on the neural network's learning capacity to learn the mapping function contained within the historical data, and then forecast with the mapping function. The advantage of the artificial neural network model is that the principle is explicit, and the idiographic form is not concerned about. There are many studies on it in the world[1,2], but those studies lay particular stress on short term forecast, and they are not competent for long term forecast for their bad extrapolate capability. Based on the analysis as above, a neural network model with good performance is constructed in this paper, and its forecast results are reasonable.

2. Present situation of energy consumption in Chongqing

In recent years, the economy of Chongqing is developed quickly. With the development of economy and the improvement of people's living standard, the total amount of energy consumption is increasing greatly, see Fig. 1[3]. From Fig. 1, it can be found out that the total amount of energy consumption increased slowly before 1980s, and also it fluctuated greatly; after 1990s, the total amount of energy consumption

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increases quickly.

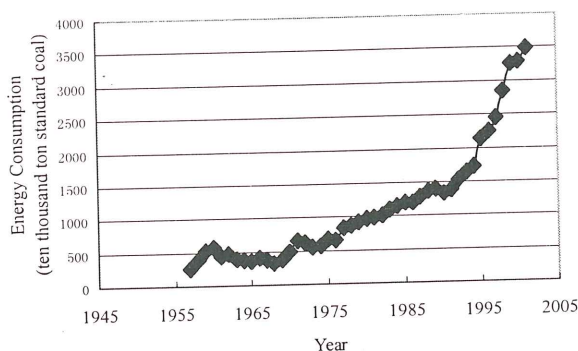


Fig.1. Energy consumption of Chongqing in the past years

3. Model construction with ANN

3.1 Introduction of ANN

ANN is a new technique developed recently. ANN is a complicate network comprising of a lot of simple process units, and it can be used to imitate the man's brain neural network and behavior. The artificial neural network is a kind of non-linear system with the function of multiple steps format information processing and parallel numerical calculation. It has the characteristic of self-learning, associative memory, error tolerance, and it simulates the intuition of man's right head[4]. At present, the ANN has been widely applied in many fields. Because the BP neural network has a good ability to process nonlinear problems for its strong nonlinear regression, it is widely used in many fields, such as artificial intelligence, signal processing, autocontrol, pattern recognition. It is the most mature neural network and the most widely used neural network, and it is the pick of the basket of feedforward neural network[5], so in this paper, the BP neural network is used to construct the forecast model.

3.2 Model construction

With its self-learning ability, the artificial neural network can understand the inner rules of complicate things. Based on the fact of the middle or long period to forecast energy demand in Chongqing, a BP neural network forecast model is constructed, which has recursion forecast ability and can forecast for a long term.

In fact, the amount of energy consumption is a time serial, and there is some statistical relationship among those data, so the energy demand can be studied with the serial method. It is difficult to describe the relation with a certain function or system of equations, but it

can be described by artificial neural network because of its good performance. In a certain period, the quality of things maintains correspondingly stabilization, but the quantity of things change very quickly. People can grasp the essential rules through studying the quantity peculiarity of things commonly. Furthermore, the analysis method of time serial can greatly reduce the workload to forecast with the historical data, so the method is necessary to be studied deeply. The forecast model in this paper contains several steps: Firstly, the neural network model learns the transformation rules and the mapping function in the historical data; secondly, the neural network model begin to forecast with the mapping function; in addition, the control parameters related with the development in the future can be introduced.

The thoughtway of the model: the certain state of things is influenced or restricted by some state before. Suppose $X(t)$ is the state of the t year, then the equation can be gained:

$$X(t)=f[X(t-1),X(t-2),\dots,X(t-n)] \quad (1)$$

n is made certain according to the different type of things. If n is too small, it can't reflect the inner rule among the things, if n is too large, it would increase the amount of calculation and workload. So n should be made certain through specific calculation.

The equation 1 only uses the inertia theory, so there is short of reliable warranty. To deal with the problem, there are two approaches: one is introducing the comparative reference, for example, in order to forecast the energy consumption of Chongqing in the future, the data of developed countries at coequal level could be introduced as reference parameter, then the forecast results would be reasonable; another approach is introducing the data or policy parameter describing the society and economy background, and make the policy parameter as the input, then let the neural network model learn the mapping function among those data. After the learning, give the society economy parameter in the future, which is up to control parameters, then begin to forecast. In this way, the reasonable long term forecast may be gained.

Based on the analysis as above, in this paper the different control strategies are taken into account, then the forecast model with fuzzy control parameters is constructed. When forecasting, the different control schemes may be input, and different results are got

accordingly. The framework of the model is shown as follows.

$$\begin{array}{lcl}
 u_{11}, u_{12}, \dots, u_{1m}, X_1, X_2, \dots, X_r, & \longrightarrow & X_{r+1} \\
 u_{21}, u_{22}, \dots, u_{2m}, X_2, X_3, \dots, X_{r+1}, & \longrightarrow & X_{r+2} \\
 \vdots & & \vdots \\
 \vdots & \longrightarrow & \vdots \\
 \vdots & & \vdots \\
 u_{k1}, u_{k2}, \dots, u_{km}, X_k, X_{k+1}, \dots, X_{n-1}, & \longrightarrow & X_n
 \end{array}$$

Control Parameter Recursion Part

In the model, m is the numbers of control parameters, r is the number of states to recursion the next state, k is the number of the stylebooks, n is the number of the total historical states.

When quantitatively analyzing those parameters as above, there are two approaches: one is establishing subjection function, and it is expressed with fuzzy numbers, but this would introduce many ectogenous inputs; another is method of graduation from 0 to 1, namely, the different value of parameters reflect different characteristic.

4. Forecast of the energy consumption in Chongqing

4.1 Data pretreatment

Influenced by many factors such as economy, society, some of the data of energy consumption vibrated greatly and deviated from the natural rules of the energy economy development, so it is necessary to pre-dispose the energy consumption and smooth them firstly. According to the energy consumption of Chongqing from 1957 to 2001, model constructed as above is used to forecast the energy consumption from 2002 to 2020. According the data from 1957 to 2001, we can see that there are some exceptional data, which divorced from the natural orbit and fluctuated greatly, so the data are not the perfect data, and should be pretreated, and the pre-processed results are shown in the Fig. 2. From the Fig. 2, we can conclude that the pretreatment data fit the original data well, and the method of data pretreatment is feasible.

4.2 Energy consumption forecast

Introducing the fuzzy control parameters into the forecast models constructed as above, this paper mainly concerns about the development rate, then establishes the fuzzy set function reflecting the varying rate of the stylebook, and adopt the graduation method from 0 to 1. When learning, the fuzzy set function is joined as

control parameters. The function relation between the increasing rate control parameters supposed and the increasing rate of energy demand is shown in Fig. 3, and the forecast control strategy is shown in Fig. 4.

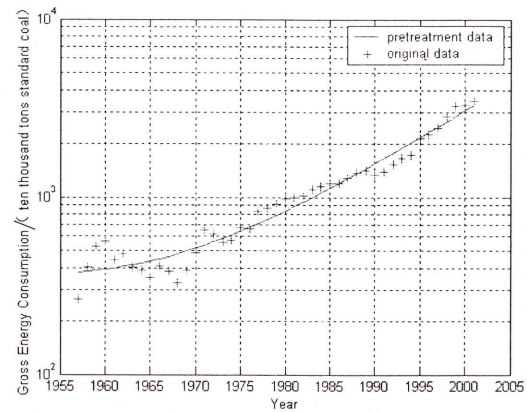


Fig.2. Data pretreatment

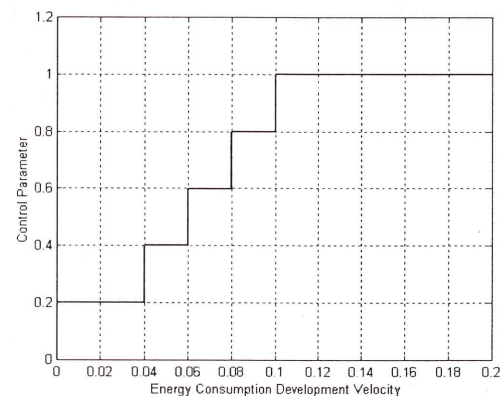


Fig.3. Function between energy consumption and control parameter

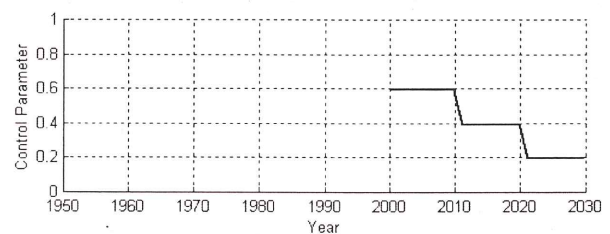


Fig.4. The variety of control parameter with year

4.2.1 Model validation

The structure of the BP neural network model is 9-15-1(input layer--hidden layer--output layer). The data from 1997 to 2001 are forecasted with the data from 1957 to 1996. The number of the stylebook is 34, and its learning precision is 1.0×10^{-4} . The forecast results are shown in table 1, and also the forecast results and the actual data are compared. From the comparison, we can see that the forecast results fit well with the actual data, and the relative errors are in the allowable scope.

Table1.Compare Between the Forecast and Actual Data
(ten thousand tons standard coal)

Year	Actual Data	Forecast Data	Relative Error	Absolute Error/%
1997	2446.45	2350.63	95.82	3.9
1998	2846.94	2695.12	151.82	5.3
1999	3256.21	3094.89	161.32	4.9
2000	3288.73	3157.11	131.62	4.0
2001	3486.05	3298.52	187.53	5.4

4.2.2 Forecast the energy demand from 2002 to 2020

After learning mapping function among the energy consumption of Chongqing from 1957 to 2001, the energy demand in the future is forecasted with the model. The forecast results are shown in Table 2. The historical data and forecast data are shown in Fig.5, which reflects the varying of the energy demand of Chongqing.

Table 2. The Forecast Results of the Energy Demand
(ten thousand tons standard coal)

YEAR	Data	Year	Data
2002	3702.19	2012	6505.19
2003	3942.83	2013	6836.96
2004	4183.34	2014	7165.14
2005	4459.44	2015	7766.08
2006	4727.00	2016	7764.71
2007	5005.89	2017	8059.78
2008	5306.25	2018	8333.81
2009	5598.09	2019	8575.49
2010	5889.19	2020	8789.88
2011	6195.42		

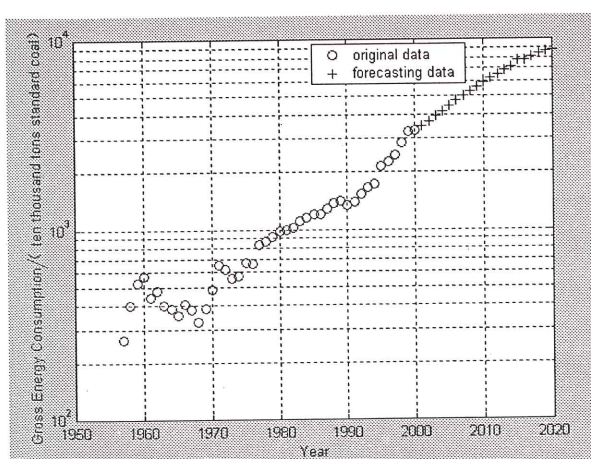


Fig.5. Varying of the energy demand of Chongqing

From the Fig.5, it can be found that the energy demand increased sharply after 1970s, and it would increase slowly after 2015. This fact fits well with the actual change trend of energy consumption, so we are

sure that the forecast results are reliable, and the model constructed in this paper is feasible.

5. Conclusions

In this paper, the macro energy consumption is the masterstroke, and forecast is the main means with the artificial neural networks developed recently. Based on the analysis of present situation of energy consumption of Chongqing, the energy demand in the future of Chongqing is forecasted with the artificial neural networks models with fuzzy control parameters reflecting stylebook character. According to the forecast result in this paper, the energy demand in Chongqing would be 8789.88 ten thousand tons standard coal in 2020. From this fact, we can see that the amount of the energy consumption is very great, but the energy supply system is a great inertial system, whose investment period is long and lag behind the demand change after a long time. That should be highly concerned about by the energy workers.

The final goal to forecast the energy demand is to establish a set of feasible and admissible energy policy or measures by all sides. Based on the analysis of the energy demand, the neural network models constructed in this paper is applied to forecast the energy demand trend quantitatively. By studying this question, it is significant for studying the energy development stratagem further, dealing with the problems existing in the future in time, guaranteeing the sustainable development of national economy, energy and environment. This study also shows that the method of forecasting the macro energy demand with artificial neural network is feasible in theory, and this study provides a new thinking manner for forecasting the macro energy demand.

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