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REGIONAL ENERGY CONSUMPTION SIMULATION BASED ON BP NEURAL NETWORK

Xueling Liu[1, 2], Yu Jin[1, 2], Weijuan Fu[1, 2] *, ShuaiLi[1, 2], Shuting Yao[1]

1 Key Laboratory of Efficient Utilization of Low and Medium Grade Energy, MOE, Tianjin University, Tianjin, 300354, People's Republic of China

2 Geothermal Research &Training Center, school of mechanical engineering of Tianjin University, Tianjin, 300354, People's Republic of China

* wjfu1018@163.com

ABSTRACT

Aiming at the establishment of energy system structure and energy network in the new-style towns in North Region of China, based on the BP neural network method, a regional energy consumption calculation model is established to calculate and predict the energy consumption in Beijing in the next 50 years. The total energy consumption, total coal consumption and total oil consumption, the total amount of natural gas consumption, and the total amount of hot water supply are predicted. Results indicate that in the next 50 years, the total energy consumption of all forms in Beijing will increase substantially, but the turning point of growth will be different. The growth of fossil energy such as coal and petroleum will be larger in the first several years, while the growth of clean energy will increase sharply during the period of the last several years.

Keywords: regional energy consumption; prediction model; BP neural network, energy system structure; energy network.

1. INTRODUCTION

With the arrival of the urbanization in China, it is prefer to the ecological civilization, green, low carbon, economical, and intensive in the construction of the urbanization [1]. Though the urbanization is helpful to the development in economy, it will bring unexpected pressure on energy consumption at the same time [2, 3]. Therefore, the planning in energy system structure, load prediction, as well as energy network design, which play an important role in the construction process of new towns. Sheng Pengfei et al. combined the simultaneous equation model and the random effect panel data to study the energy consumption associated with urbanization in China, and found that urbanization had a great impact on China's energy utilization and efficiency [2]. Zagrebina et al. established a power prediction model based on recurrent neural network, which was proved to be with higher prediction accuracy, and was help to reduce the cost of electricity in Russia and improve energy efficiency significantly [3]. Ye et al. established a new energy consumption prediction model by optimizing the discrete gray model in the grey system theory, which can be applied to any field of energy consumption prediction (oil consumption, natural gas consumption, etc.)[4]. At the same time, Xiao et al. optimized the predictive performance of energy consumption prediction model by introducing AdaBoost integration technology and back propagation neural network [5]. Thus, it is of practical significance to study the trend of energy consumption and accurately predict the energy consumption in a certain stage in the future. The prediction methods of energy consumption was mainly concentrate on regression analysis [6-8], analytic hierarchy [9], grey theory [10-12], artificial neural network[13, 14], time series[15-17], trend extrapolation, support vector machine[18] [19, 20] and other methods. Among them, the artificial neural network has many advantages, such as the excellent nonlinear mapping ability, little requirements on the datum.

Previous investigations on regional energy

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consumption mainly focus on the development of datum processing methods and the prediction on one kind of energy. In present work, both the thermal energy consumption and various types of energy consumption in the whole region are considered, which is expected to understand the overall energy consumption characteristics of China's new urban energy consumption. By the way, suburb of Beijing is supposed to be the target area, the energy consumption in different kinds of energy, involving coal, petroleum, natural gas, electricity and heating load are predicted in following 50 years according to the geographical location, climatic conditions, urban function of the city. In present simulation, BP artificial neural network method is used to establish the regional comprehensive energy consumption mathematic model. The energy consumption structure and the variation of the different kinds of energy consumption in the future are analyzed, which is help to the establishment of the energy system structure and the energy network of the new town.

2. REGIONAL ENERGY CONSUMPTION CALCULATION MODEL

2.1 Calculation Model

Aiming at the establishment of energy system architecture and energy network in new towns in the future, relevant analysis and regression fitting are carried out. BP neural network method is used to construct the regional energy consumption calculation model, which is used to predict the relevant energy consumption situation in Beijing in the next 50 years. The calculation process is shown in Figure 1.

BP (Back-propagation) artificial neural network is one of the most widely used models in artificial neural networks. It has the advantages of processing information in parallel, powerful self-learning, self-organization, self-adaptive ability and fault tolerance. The input and output model, action function model, error calculation model and self-learning model of BP network are used.

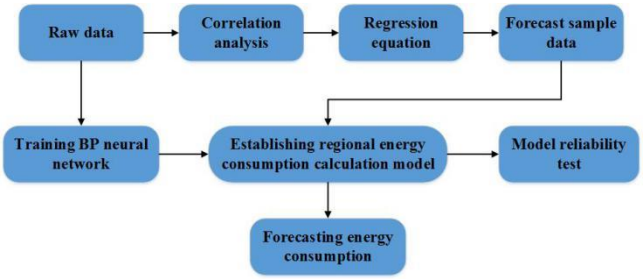

Fig.1 Regional energy consumption calculation model research technology line

The output model of implicit node is:

$$Q_{\mathrm{j}} = \mathrm{f}\left(\sum W_{\mathrm{ij}}\, X_{\mathrm{i}} - q_{\mathrm{j}}\right)$$

Output model of the output node is:

$$Y_{\mathrm{k}} = \mathrm{f}(\sum T_{\mathrm{ik}}\, O_{\mathrm{j}} - q_{\mathrm{k}})$$

Where f is a nonlinear action function, q is a neural unit threshold. The function function in the function model generally takes continuous values in (0,1) , sigmoid function:

$$\mathrm{f(x)} = 1/(1 + \mathrm{e}^{-x})$$

Error calculation model:

$$E_q = 1/2\,(t_{pi} - O_{\mathrm{pi}})$$

Where t_{pi} is the expected output value of the node, O_{pi} is the node to calculate the output value.

Self-learning model:

$$\Delta W_{ij}(n+1) = h\emptyset_i Q_j + a\Delta W_{ij}(n)$$

Where h is the learning factor; $\emptyset_i$ is the calculation error of the output node i; a is the momentum factor. The topology of the BP neural network established is shown in Figure 2. The BP neural network has a 3-layer neural network, which includes an input layer, an output layer, and an implicit layer.

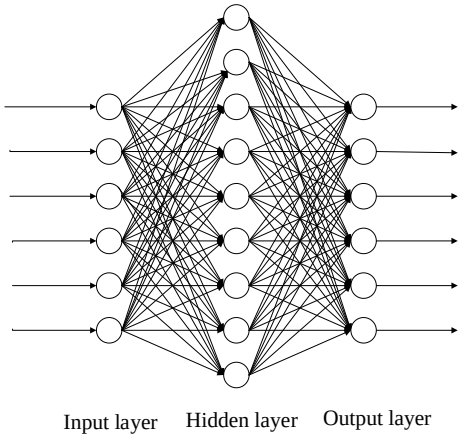

Fig.2 BP neural network topology

2.2 Model Reliability Test

Energy consumption of different kinds of energy in Beijing from 2005 to 2016 is obtained from the reported datum by the National Bureau of Statistics. That energy consumption from 2005 to 2010 is used as the learning training sample of the calculation model, and the energy consumption from 2011 to 2016 is predicted through the calculation. The simulated results are compared to the reported datum by the National Bureau of Statistics at the same time, as shown in Fig. 3. It can be found that the simulated results of the energy consumption are in good agreement with reported results for all kind of energy. The maximum of the error is 1.98%. Therefore, this calculation model can be used to predict the energy consumption for the new town of Beijing in the future.

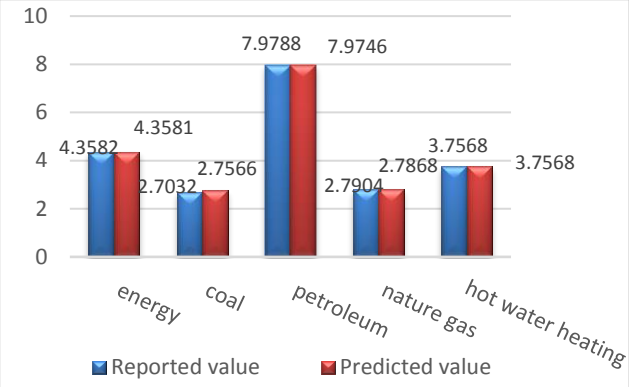

Fig.3 Evaluation of the calculation model

3. RESULTS AND DISCUSSTION

The energy consumption calculation model of the region is used to predict the energy consumption of various forms in Beijing in the next 50 years. The total energy consumption refers to the sum of various energy sources consumed by various sectors of the national economy and households in a certain period of time. In present work, the thermal energy consumption and various types of energy consumption in the whole region are both considered, which is expected to understand the overall energy consumption characteristics of China's new urban energy consumption.

The total energy consumption is shown in Figure 4. It's found that the total energy consumption rises first with time and then stabilizes. To a certain extent, the change in energy demand is closely related to economic development. Economic development promotes energy technology and improves energy efficiency and then has an impact on energy requirement. During 2017-2027, the growth rate of total energy consumption is very fast, which indicates that energy demand is growing during this time. That is mainly due to the fact that the development of economic in China's is in a rising period, which results in much more energy demand. During 2028-2067, the overall trend of energy consumption tends to be stable, and the growth rate has dropped significantly. This may be due to the fact that economic development in China tends to be stable and energy consumption capacity tends to be stable in the future.

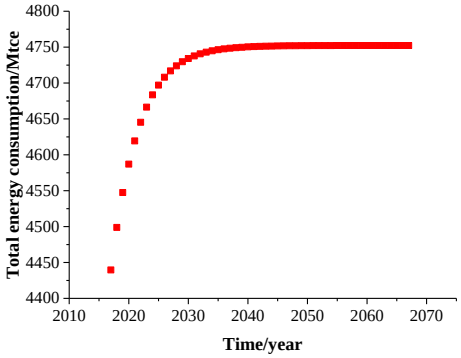

Fig.4 Total energy consumption

Figure 5 shows the forecast results of total coal consumption in the next 50 years. From this figure, it can be found that the development trend of total coal consumption is the same as the development trend of total energy consumption, which has risen rapidly at a relatively fast growth rate in the early stage, and then has remained stable for a long time. The sustained growth of coal consumption in the early stage is mainly related to China's current coal-based energy consumption structure. At present, China has begun to control the amount of coal mining and usage, and China's coal-based energy consumption structure will be changed. According to the prediction results, the growth of total coal consumption will be effectively controlled around 2030.

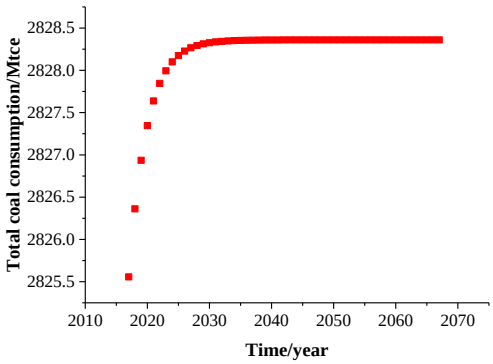

Fig. 5 Total coal consumption

Figure 6 shows that the total petroleum consumption will increase exponentially, which is resulted from the prosperity and development of petroleum consumption industries, such as transportation brought about by the rapid development of economy in China. The rapid economic development has promoted the continuous rise of total petroleum consumption, and industrial petroleum consumption demand and transportation oil demand are the two main reasons. It has been reported by the National Bureau of Statistics that the number of Chinese civilian vehicles will rise sharply to 226,448,100 by 2030. The rapid growth of automobiles has led to the continuous increase in demand for petroleum.

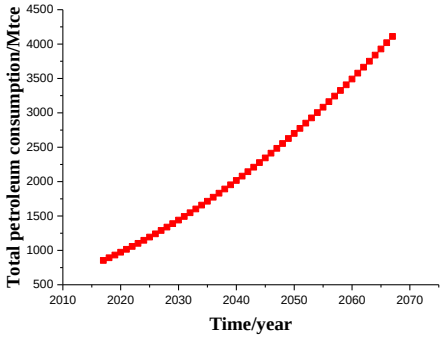

Fig. 6 Total petroleum consumption

As shown in Figures 7, the growth rate of total natural gas consumption in the early stage is relatively slow, and the growth rate is higher in the final years, which is consistent with the future development trend of energy consumption in China. In order to further optimize the power supply, power demand side management will be implemented continually and intermittent power generation capacity of renewable energy will be continuously optimized.

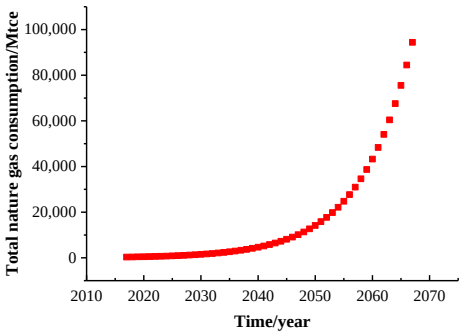

Fig. 7 Total natural gas consumption

The prediction of total hot water heating is shown in Figure 8. It shows that the total amount of hot water heating has been in a stable state, which is mainly due to the rapid development of heating with renewable energy. The potential of utilization of renewable energy in heating, such as solar energy, geothermal energy and biomass energy, will be more than 30% of the total heating market in China by 2030. Therefore, the total amount of hot water supplied by traditional ways may be stable.

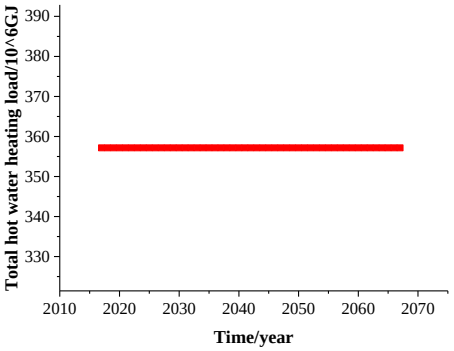

Fig. 8 Total hot water heating load

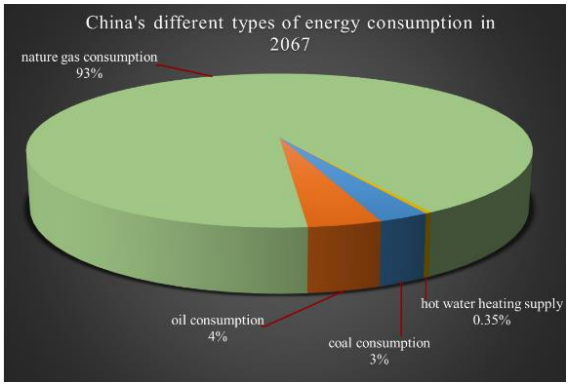

Fig. 9 China's different types of energy consumption in 2067

The different types of energy consumption in China

in 2067 are shown in Figure 9. It can be found that the proportion of nature gas is the highest, reaching more than 90%. While the consumption ratios of petroleum and coal decrease obviously. it indicates that the energy consumption structure will be the characteristics of cleaner and lower carbon in China.

4. CONCLUSION

In order to study the establishment of energy system architecture and energy network in new towns in the future, BP neural network method is used to establish a regional energy consumption calculation model, and the future energy consumption of Beijing is predicted and analyzed in present work. According to the predicted results of different kind of energy consumption in the next 50 years and the correspond analysis, the following conclusions can be obtained:

The total energy consumption and total coal consumption in Beijing will have a substantial increase in the next 10 years, and the growth inflection point will appear around 2030. The total oil consumption will maintain a relatively fast growth rate in the next 50 years. Clean energy such as natural gas will be a rapid growth around 2040. The total amount of hot water heating remains stable. In the next 50 years, reform of energy consumption structure is still need to be promoted vigorously.

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