Analysis of Supply and Demand Situation of Low Carbon Energy in China Based on Grey System Neural Network

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Abstract. At present, with the rapid development of the world economy, the demand for energy and resources is increasing day by day. Resource scarcity and environmental deterioration have become important issues facing the world. The energy development mode based on traditional fossil energy cannot support the rapid economic development of our country, which makes the energy transformation of our country imperative. In this paper, the grey GM (1,1) model and artificial neural network are combined to modify the prediction results of GM (1,1) model. In order to make GM(1,1) model have higher prediction accuracy in medium and long-term prediction, partial data GM(1,1) model groups are respectively established by using partial data sequences of original data, and the nonlinear mapping relationship between fitting values and original data is calculated by establishing this partial GM(1,1) model groups by using BP neural network. The calculation results show that the prediction method is reliable and has high prediction accuracy.

1. Introduction

In the study of energy strategy, the constraints of resources and environment are placed in an increasingly important position. As the global demand for low carbon and clean development continues to rise, and China vigorously promotes the in-depth adjustment of energy structure and industrial replacement and upgrading, natural gas will have a more prominent strategic position in China's energy resources in the future [1]. From the end of the 20th century to the beginning of the 21st century, China has formed an energy development route with power construction as the core. A large number of thermal power plants have been put into use continuously, which has gradually balanced the power supply and demand in China, ending the stage of insufficient energy supply in China [2]. In order to ensure energy security and safeguard the social environment, while developing and utilizing energy and resources, China should regard sustainable development as an important objective of social, economic and energy development, continuously develop and utilize new low carbon energy and reduce environmental pollution. Low-carbon energy is the foundation of green economy and low-carbon economy. Green and low-carbon energy strategy is the weathervane for China to enter ecological civilization.

At present, many different forms of neural networks have been used for industrial and economic prediction. The grey system theory does not pay attention to what the grey information is or how it acts on the system. The technical system is based on data processing, system analysis, modeling, prediction, decision-making, control and evaluation, and efforts are being made to form a grey mathematical system based on grey hazy sets. The organic combination of neural network and grey system can complement each other. This paper analyzes the basic concepts and modeling mechanism of grey prediction model.
and neural network, and studies the combination of grey GM(l,1) model and BP neural network to build China's low carbon energy supply and demand model.

2. China's Energy Supply and Demand Situation

2.1 Crude oil production is declining year by year, and crude oil consumption and imports continue to rise. The demand for low-carbon and clean development is the most direct factor leading to the adjustment of China's energy structure, and is also the biggest influencing factor leading to the possible breakthrough of future natural gas consumption in various scenarios predicted today [3]. Domestic oil demand continues to grow and the gap between supply and demand continues to widen. In the past 10 years, China's oil demand has increased by $5 \times 10^6$ barrels/d, which is by far the country with the largest increase in oil demand. In recent years, China has stepped up the construction of natural gas transmission pipelines and coastal lng terminal. The natural gas supply pattern has shown a situation of "west-to-east gas transmission, sea gas landing and north-to-south gas southward". From a "high carbon" energy structure to a "low carbon" energy structure, a safe, scientific and green modern energy industry system will be constructed. It requires "taking into account China's sustainable development, energy security, economic competitiveness and energy conservation and emission reduction capabilities, actively making efforts to change the mode of economic development, change the mode of production and consumption, and strengthen technological progress, which is a low-carbon scenario that is possible to achieve." The change of total energy consumption mainly occurs in industry and the tertiary industry. The change of energy consumption in industry is in good agreement with the change trend of total energy consumption in China, which shows that the change of industrial energy consumption is the main factor affecting the change of total energy consumption in China.

2.2 Natural gas production has increased steadily, and consumption and import have both increased significantly. The carbon emission intensity requirement under the low-carbon scenario will force China to deepen energy restructuring. Compared with developed countries, China has a high proportion of coal and a low proportion of oil, natural gas and clean energy. The average annual growth rate of China's oil demand is 2.32% and 2.15% respectively, while the average annual growth rate of natural gas demand in the same period is 6.09% and 5.94% respectively [4]. Industry has the largest share of energy consumption, accounting for China's total energy consumption, further highlighting that industry plays the most important role in China's energy consumption. The proportion of energy consumption in the tertiary industry is second only to industry, with a proportion of about. Guiding policies and regulating laws and regulations play an important role in the growth of consumption and the growth of the industry, and are crucial to increasing the proportion of natural gas application and promoting the marketization of the natural gas industry. With the orderly promotion of “the belt and road initiative” mineral resources cooperation, China's future import of natural gas from Central Asia is expected to further increase.

2.3 The proportion of clean energy consumption continues to rise with great potential for development. Adjusting China's energy structure and reducing the production and consumption of high carbon-emitting energy (especially coal) are our urgent wishes, but its implementation cannot leave China's reality. The production and consumption of hydropower energy will grow steadily and continuously for some time to come. Among various industries, industrial energy intensity has the characteristics of high level and large fluctuation range, followed by the tertiary industry. The primary industry and construction industry have lower and more stable energy intensity. Natural gas, hydropower, nuclear power, wind power and other clean energy consumption accounted for 20.5% of the total energy consumption [5]. China's development stage, national conditions and industrial situation should be fully judged, a reasonable energy strategy should be formulated, passive coping should be changed into active operation, adjustment objectives and stability should be taken into account, and energy consumption structure should be gradually adjusted. With the change of China's energy policy and the accelerating pace of new energy development, the proportion of coal in China's energy
consumption structure will continue to decline in the future. The main reason is that the low-carbon energy industry meets the needs of the development of green economy, is the guarantee for the development of efficient, green and safe energy in our country, and is also the requirement for the harmonious development of economy, environment and energy. Therefore, technological progress can improve the energy efficiency of various industries and even the entire economic system.

3. Algorithm Model

3.1 Grey system GM (1,1) model. The process of grey system modeling is to process the original data sequence that changes in a certain range and a certain period of time through a certain method to generate relatively regular time series data, thus establishing the dynamic model of development and change of abstract system. China is the main body of consumption increment, trade flow, capital output, technology output and infrastructure construction. When the system is impacted, due to the system's own motion behavior, the interference is continuously amplified, which eventually distorts the predicted data. The development and utilization of renewable energy are increasingly being paid attention to by many countries, especially those with energy shortages. In the medium and long term, the effect of urbanization rate on energy demand is higher than that of urbanization rate on GDP per capita. Some unclear systems include incomplete element (parameter) information, incomplete structure information, incomplete relationship information and incomplete operation behavior information. The research shows that the model of the original data and its smooth characteristics are the two main factors that affect the accuracy of the grey model. The main method is to extract valuable information mainly through the generation and development of "part" of known information, so as to realize correct description and effective control of system operation behavior and evolution law.

Let $X^{(0)}$ be the original non-negative data sequence:

$$X^{(0)} = (x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n))$$ (1)

Remember the one-time accumulation $(1-AGO)$ sequence with $X^{(1)}$ as $X^{(0)}$:

$$X^{(1)} = (x^{(1)}(1), x^{(1)}(2), \ldots, x^{(1)}(n))$$ (2)

Among them,

$$x^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i), k = 1, 2, \ldots, n$$

Let $S^{(1)}$ be the nearest mean value $(MEAN)$ of $X^{(1)}$ to generate a sequence:

$$S^{(1)} = (s^{(1)}(2), s^{(1)}(3), \ldots, s^{(1)}(n))$$ (3)

Among them,

$$s^{(1)}(k) = 0.5x^{(1)}(k) + 0.5x^{(1)}(k-1).$$

The basic form of $GM (1,1)$ model is:

$$x^{(0)}(k) + es^{(1)}(k) = l$$ (4)

Where $e$ is called the development coefficient and $l$ is the grey action quantity.

The research object of grey system theory is "small sample" with "part" of information known and part of information unknown, and "uncertain system with poor information". Through the generation and development of "part" of known information, we can understand and solve practical problems. The growth rate of China's energy production and consumption is also gradually slowing down, showing a trend of fast growth first and slow growth later. The grey GM (1,1) prediction model regards the observation data sequence of renewable energy consumption as a grey process that changes with time, and uses the time sequence to determine the parameters of differential equation, thus establishing the model of corresponding differential equation and making prediction [6]. However, the grey system theory has no strict requirements on the sample size and does not require any distribution, which is very
different from the probability statistical models such as time series analysis and multivariate analysis, which require large samples.

3.2 **BP neural network model.** BP neural network model, i.e. error backward propagation neural network, is the most widely used type of neural network model. It is divided into input layer, hidden layer and output layer. The differences in energy intensity among industries and the characteristics of the overall industrial structure of the economy are helpful to guide the direction of optimizing a country's industrial structure. It is inappropriate for some people to list the efficient and clean utilization of coal and the new generation of nuclear power and large hydropower as new energy sources. However, new energy sources emphasize the "new" of their types and technologies. Until now, they are still constrained by technological level and economic margin and have not yet been used on a large scale. For the input signal, BP neural network must first propagate forward to the hidden layer node, then propagate the output signal of the hidden node to the output node after passing through the action function, and finally give the output result. The gray system method is used to solve the part with obvious gray characteristics and no distributed parallel calculation, while the neural network is used to solve the part without gray characteristics that belongs to black box, and there is no direct relationship between the two [7].

There are 4 neurons in the input layer and 4 neurons in the output layer of the neural network, with one hidden layer in the middle. The number of nodes in the hidden layer can refer to the empirical formula:

\[
I = \sqrt{i + m + \alpha} \quad (5)
\]

Where: \(m\) is the number of output neurons; \(n\) is the number of input neurons; \(\alpha\) is a constant between [1,10].

Grey prediction method is used to predict the original irregular monitoring data, and the combination of the obtained prediction result value and the corresponding real value is modeled by neural network. Therefore, it can solve the problems that cannot be solved or solved by conventional information processing methods, especially those that belong to thinking, association, reasoning and consciousness. However, it is difficult to directly use the grey differential equation in practical application, so the grey differential equation should be whitened. We can construct a BP network to whiten the grey parameters of grey differential equations. The training samples used in network training are composed of input vectors and target vectors [8]. In the process of learning and training, the neural network continuously compares the actual output results with the target output, and adjusts the network weights and thresholds according to certain rules or algorithms, so that the output of the network gradually approaches the target output. No matter in terms of economic output, energy consumption or energy intensity, industry occupies a leading position. In order to highlight the influence of industry, the secondary industry is still divided into industry and construction. The actual predicted renewable energy consumption is used as the output of the network to train the neural network, thus avoiding the artificial inaccuracy of the analysis of influencing factors.

4. **Analysis of Combined Forecast Model Based on Grey System and Neural Network**

The output of neural network is actually the grey number according to the definition of grey number in grey system theory. Therefore, the neural network itself contains gray content. Among them, a positive energy saving amount indicates that technological progress has improved energy efficiency, and a negative energy saving amount further indicates that technological progress has not brought about energy saving, but has instead promoted an increase in energy consumption. Renewable energy is often mentioned in the discussion of sustainable development. Most new energy sources (especially wind energy and solar energy) and hydropower are among them, but nuclear energy should not be included in them [9]. The country should gradually change its orientation for the development of oil and gas enterprises, and shift its orientation from supply protection to efficiency protection. Enterprises should assume more economic responsibilities and reduce political responsibilities so that enterprises can participate in market competition in a more flexible and changeable way, thus creating truly competitive international oil and gas enterprises. China's low carbon energy sources such as hydropower and nuclear
energy are mainly used in terminals in the form of electric energy, while China's import and export trade of electric power is very small. Renewable energy generation has become an important part of the electricity market. Through the integration of information, the specific uncertainty of a single prediction is dispersed and the overall uncertainty is reduced, thus improving the prediction accuracy. Compared with single prediction, combined prediction has higher prediction performance and less risk of prediction error.

Considering that the result error of grey system prediction is large after a long time, the metabolic prediction mode is adopted. As shown in fig. 1. After completing the network training, the renewable energy consumption predicted by the grey system in 2015 is taken as the network input. After the neural network correction, the renewable energy consumption in 2016 is very close to the measured renewable energy consumption in 2016, with a relative error of only -2.18%. Compared with the relative error of the grey system prediction model of -10.82%, the accuracy of the prediction result is greatly improved.

Figure 1 Neural network training results

China's energy development faces a grim situation, many challenges and arduous tasks. The energy problem involves many aspects such as energy policy, energy science and technology, energy market, energy environment, etc. Using the predicted value from 2015 to 20017, choose a as the input of the neural network to predict the renewable energy consumption from 2021 to 2023. See Table 1 for the low-carbon energy consumption prediction of the grey system modified by the neural network.

Table 1 Forecast results of low carbon energy consumption of grey system after neural network correction

| Year | Nuclear power | Hydropower | Renewable energy sources |
|------|---------------|------------|-------------------------|
| 2021 | 2.33×10^9     | 2.58×10^10 | 9.94×10^9               |
| 2022 | 2.41×10^9     | 2.69×10^10 | 15.47×10^9              |
| 2023 | 2.89×10^10    | 2.91×10^10 | 18.22×10^10             |

In the global energy structure, 34% is oil, 23% is natural gas, 28% is coal, 10% is renewable energy and 5% is nuclear energy. China is rich in energy resources, but its per capita share is low. Coal has long occupied a dominant position. The proportion of high-quality resources such as oil and gas and low carbon energy is low. The electrification level is not high. The environmental pollution problem is becoming more and more serious. The dependence on foreign oil is increasing. Under the process of increasingly strengthening marketization, profitability is the premise of sustainable development of enterprises and industries. According to the prediction of low-carbon and intensified low-carbon scenarios, the coal demand in 2021 and 2023 at their peak states will reach 22.07×10^8t standard coal and 20.10×10^8t standard coal, which are about 31×10^8t and 28.1×10^8t raw coal respectively based on 1t standard coal equivalent to 1.4t raw coal.

The complete fusion of neural network and grey system is called grey neural network, and its constitution adopts different ways for different neural networks. In the process of operation, once the absolute value of the prediction error is found to be greater than the threshold value, a special point is considered to occur, and the neural network learning process is started. At the same time, it also takes
into account the more or less correlation between the front and back data, and makes full use of the self-learning, nonlinear mapping and parallel distributed processing capabilities of the neural network. The supply-demand relationship between hydropower and nuclear power in China is relatively harmonious, while the supply-demand relationship of renewable energy industry needs further improvement due to its early stage of development. Based on the national conditions of resources, accelerate the development and utilization of traditional energy resources and expand the scale of natural gas consumption. We will implement structural reforms on the energy supply side, accelerate the reform of the oil and gas and electricity systems, and form an effective competitive market mechanism. Strengthen benefit orientation, explore a number of new areas and new areas, tap a number of new types of resources, and develop a number of projects that highlight benefits. In other words, in the composition of China's power industry, the proportion of installed capacity of hydropower and some new energy sources is significantly higher than the proportion of actual power generation. The accumulation generation in GM(1,1) model shows a monotonic increasing trend in sequence, which is more suitable for BP neural network to approximate. Therefore, it is feasible to combine the grey GM(1,1) model with BP neural network to construct the grey-neural network combination model.

5. Summary
Optimizing the energy structure and replacing petrochemical energy with clean, green and renewable new energy have become the mainstream of protecting the ecological environment in the world. The combined prediction model of grey system and neural network introduced by the author in this paper makes full use of the advantages of less information and simple method required for grey prediction modeling, as well as the strong non-linear mapping capability of neural network. A combined forecasting model combining grey system and neural network is established, and a forecasting model of China's low carbon energy supply and demand situation based on grey GM(1,1) model and BP neural network is proposed. The calculation results show that the prediction value modified by the neural network is much higher than the prediction value of the original GM(1,1) model, and the convergence rate of neural network training is faster. With the in-depth research on the integration of grey system and neural network technology, a new and effective way will be found to solve the complex system which can be reduced to grey system.

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