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Research and Empirical Study on the Healthy Development dynamic model of electric power system Based on China's Resource Endowment

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Abstract. Based on the macro data of China's power development in recent years, the paper constructs a dynamic model structure for balanced development of energy generation systems. By modifying, optimizing and verifying it, the optimal dynamic model based on the China's energy endowment system is derived. And using it, the paper makes a comprehensive in-depth analysis of the long and short-term dynamic variation process and affecting factors of electric power in China, makes a rational study on the trend of complementary multi-source fusion and development as well as the optimal ratio of solution in China's future power industry. Through an empirical analysis, the simulation degree and reliability of provided decision is proved to be relatively good. While China's energy has been developing rapidly, there are still some universal problems such as deficient power generation absorption, less reasonable power structure, power transmission channel and so on. Therefore, the paper also puts forward suggestions and solutions on how to strengthen the whole process management of energy development and utilization, formulate all –dimensional policy system etc. in order to promote the development of electric power in China.

1. Introduction

China's energy consumption and emissions of pollutants rank first in the world, resource and environmental costs are too heavy, poor structure, low efficiency and energy security are the main problems of China's energy [1]. " Strengthening energy and resource conservation and ecological environment protection, enhancing sustainable development capacity, developing clean energy and renewable energy, and making the proportion of renewable energy increase significantly" has been included in China's development planning report. All countries in the world will also vigorously develop renewable energy as one of the important means to reduce greenhouse gas emissions and delay climate change. Responding to global climate change has become another important driving force for the development and utilization of renewable energy [2]. The Chinese government has proposed "to achieve the goal of non-fossil energy accounting for 15% of primary energy consumption by 2020, and carbon dioxide emissions per unit of GDP by 2020 is 40%-45% lower than in 2005" [3]. Based on the macroscopic data of China's power energy development and utilization, this paper constructs a dynamic model of power system equilibrium development based on China's energy endowment, systematically analyzes and judges the future development trend and the ratio of various types of energy power generation structure, and the science of energy supply and demand. System analysis and prediction, and

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put forward countermeasures and suggestions to promote China's energy structure transformation and scientific development.

2.China's energy development and utilization status and future development trend

2.1. Current status of energy development and utilization in China

China's energy structure is dominated by coal. At present, coal accounts for more than 60% of China's primary energy consumption, far higher than the world average of 29%. Due to the difficulty in optimizing the energy structure, it is predicted by experts that the proportion of coal in China's primary energy structure will not be lower than 50% in 2030 [4]. As power development will face a more rigid resource environment constraints, in order to move from a traditional energy system that relies excessively on coal to a clean, low-carbon, efficient and diverse modern energy system. In recent years, under the premise of meeting the needs of economic development, the national power installed capacity has obvious structural adjustment effects, and the proportion of non-fossil energy installed capacity such as hydropower, nuclear power and wind power continues to rise. By the end of 2017, China's hydropower, wind power and solar power generation capacity reached 340 million, 160 million and 130 million kilowatts respectively [5], the new energy scale ranked first in the world, and the proportion of non-fossil energy power generation installed increased from 24.23% in 2005. 38.1% by 2017 [6].

2.2.China's energy endowment and future development trend

China's energy sources are characterized by a wide variety, wide distribution but uneven distribution and low per capita possession. 85% of the coal is distributed in the central and western regions; 81.13% of the petroleum resources are distributed in eight major regions such as Bohai Bay, Songliao and Tarim; 83.64% of the natural gas resources are distributed in nine regions including Tarim, Sichuan and Erdos; 67.8% of the resources of the resources are mainly distributed in the southwestern region; the wind energy resources are mainly distributed in the “three north” areas of the northeast, northwest and north China [7]. With the development of society, the historical stage of the traditional fossil energy gradual withdrawal from the main energy supply is an inevitable trend. New energy power generation will gradually become the main power source of the power system, and it will play an important role in optimizing China's energy structure, ensuring energy supply security, and promoting energy conservation and emission reduction. More important role.

3. Power System Balanced Development Dynamics Model

Based on China's energy endowment, establishing a reasonable power balance development system, formulating practical and feasible development goals, and realizing the sustainable development of China's power industry, it is necessary to use system engineering ideas and price growth theory, and consider the interaction between various factors and external policy factors. The impact of the establishment of a dynamic model of the impact of various types of energy on the balanced development of power systems.

3.1.Basic equation of the model

In this paper, x_i ($i=1,2,\cdots,n$) indicates the current power generation capacity (unit: Gwatts), M_i ($i=1,2,\cdots,n$) represents the amount of power generation investment (unit: 100 million yuan), indicating the current average power generation cost (unit: yuan/watt). Subscripts represent coal, hydropower (sump), wind power, nuclear power, gas power generation, photovoltaic power generation, biomass power generation, waste-to-energy, geothermal tidal power generation, solar power generation, etc. Where , and x_i 、 M_i 、 p ($i=1,2,\cdots,n$) are functions of time.

Based on the Lanchester-based war model modeling idea [8], the power development prediction model studied in this paper is proposed. First, establish a numerical model for the growth of power generation capacity of various types of energy:

$$\begin{cases} \dfrac{dx_1}{dt} = a_1 x_1 + b_1(t, x_1) + f_1(t, x_1, x_2, \cdots, x_n) \\ \dfrac{dx_2}{dt} = a_2 x_2 + b_2(t, x_2) + f_2(t, x_1, x_2, \cdots, x_n) \\ \qquad\qquad \vdots \\ \dfrac{dx_n}{dt} = a_n x_n + b_n(t, x_n) + f_n(t, x_1, x_2, \cdots, x_n) \end{cases} \tag{1}$$

The coefficient a_i ($i = 1, 2, \cdots, n$) indicates the basic annual compound growth rate of the installed capacity of the corresponding energy project; $b_i(t, x_i)$ ($i = 1, 2, \cdots, n$) indicates the time-dependent growth function caused by factors such as construction cost, fuel cost, technological progress, and operator's operating efficiency; $f_i(t, x_1, x_2, \cdots, x_n)$ ($i = 1, 2, \cdots, n$) The interaction effect between the project costs affected by environmental protection issues, electricity price reforms, etc., is related to time.

Secondly, establish a growth model for each investment amount:

$$\begin{cases} \dfrac{dM_1}{dt} = c_1 M_1 + g_1(x_1, M_1) + h_1(t, M_1, M_2, \cdots, M_n) \\ \dfrac{dM_2}{dt} = c_2 M_2 + g_2(x_2, M_2) + h_2(t, M_1, M_2, \cdots, M_n) \\ \qquad\qquad \vdots \\ \dfrac{dM_n}{dt} = c_n M_n + g_n(x_n, M_n) + h_n(t, M_1, M_2, \cdots, M_n) \end{cases} \tag{2}$$

The coefficient c_i ($i = 1, 2, \cdots, n$) indicates the basic annual compound growth rate of the corresponding project; $g_i(x_i, M_i)$ ($i = 1, 2, \cdots, n$) indicates the investment growth function caused by the change in installed capacity; $h_i(t, M_1, M_2, \cdots, M_n)$ ($i = 1, 2, \cdots, n$) indicates the interaction between the project investments affected by the operating characteristics, electricity price mechanism and other financing arrangements. Influence function, which is related to time. The corresponding average electricity production price formula can be obtained:

$$p = \frac{\bar{M}}{\bar{x}} = \frac{\sum_i M_i(t)}{\sum_i x_i(t)} \tag{3}$$

3.2 .Model parameter analysis

Based on China's energy endowment, coal power, hydropower, wind power, gas power generation and nuclear power account for about 95% of the current installed capacity of power generation [9]. In order to simplify the computational modeling, only the actual model is used. Consider the prediction calculations of the above five types of main power generation installations, and give prediction schemes for each parameter.

3.2.1. Numerical model of power generation capacity growth

$b_i(t, x_i)$ ($i = 1, 2, \cdots, 5$) indicates a time-dependent growth function caused by factors such as construction cost B(t), fuel cost F(t), technological advancement T(t), and operating benefit E(t) generated by power generation enterprise operations. Shows:

$$b_i(t, x_i) = \frac{E_i(t) \cdot T_i(t)}{k_0 \cdot B_i(t) + l_0 \cdot F_i(t)} \cdot x_i \tag{4}$$

For the sake of simplicity, E_i, T_i, is not considered in the model.

$f_i(t, x_1, x_2, \cdots, x_5)$ ($i = 1, 2, \cdots, 5$) indicates the interactive influence function of each project cost affected by environmental protection issues and electricity price reform policies. According to the central government's proposal, by 2020, China's non-fossil energy will account for 15% of total primary energy consumption, and by 2020, China's carbon dioxide emissions per unit of GDP will fall by 40%-45%

compared with 2005 [10]. Considering the proportion of carbon dioxide generated during the production of coal-fired power, hydropower, wind power, gas-fired power generation and nuclear power, Taking coal power generation x_1 as the basic comparison parameter, That is to say, the increase of coal power per unit time is C_1x_1, the increase of hydropower is C_2x_1, the increase of wind power is C_3x_1, the increase of gas power generation is C_4x_1, and the increase of nuclear power is C_5x_1, and satisfy $C_1+C_2+\cdots+C_5=0$.According to the above assumptions, the interactive influence function of various types of fuel power generation can be expressed by the following formula:

$$f_i(t,x_1,x_2,\cdots,x_5)=C_i\cdot x_1\ (i=1,2,\cdots,5) \tag{5}$$

3.2.2.Numerical model of growth in investment amount

The investment growth function $g_i(x_i,M_i)$ ($i=1,2,\cdots,n$),caused by the change in installed capacity can be derived from each specific case.

In recent years, investment in the power generation industry has undergone a significant structural transformation. As investment in thermal power generation (especially coal-fired power) has decreased and hydropower investment has increased, the wind power industry has experienced overcapacity and falling profit margins after experiencing rapid growth [11].

$h_i(t,M_1,M_2,\cdots,M_5)$ ($i=1,2,\cdots,5$) represents the interactive influence function of the investment amount of each project affected by the operating characteristics, electricity price mechanism and other financing arrangements. The function of this group is related to time.

The investment in coal power per unit time increases D_1M_1, the increase in hydropower is D_2M_1, the increase in wind power is D_3M_1, the increase in gas power is D_4M_1, and the increase in nuclear power is D_5M_1. According to the above assumptions, the interactive influence function of various types of energy power generation investment can be The formula indicates:

$$h_i(t,M_1,M_2,\cdots,M_5)=D_i\cdot M_1\ (i=1,2,\cdots,5) \tag{6}$$

3.2.3. Model calculation

The calculation model can be changed to:

$$\frac{d}{dt}\begin{pmatrix}x_1\\x_2\\x_3\\x_4\\x_5\end{pmatrix}=\frac{1}{10}\begin{pmatrix}0.606&0&0&0&0\\0.015&0.837&0&0&0\\0.01&0&1.97&0&0\\0&0&0&1.62&0\\0.005&0&0&0&2.05\end{pmatrix}\begin{pmatrix}x_1\\x_2\\x_3\\x_4\\x_5\end{pmatrix} \tag{7}$$

$$\frac{d}{dt}\begin{pmatrix}M_1\\M_2\\M_3\\M_4\\M_5\end{pmatrix}=\frac{1}{10}\begin{pmatrix}1.39&0&0&0&0\\0.02&1.31&0&0&0\\0.02&0&0.99&0&0\\0&0&0&1.40&0\\0.06&0&0&0&0.77\end{pmatrix}\begin{pmatrix}M_1\\M_2\\M_3\\M_4\\M_5\end{pmatrix} \tag{8}$$

When considering the variation of each parameter function with time, both equations (7) and (8) are 5-dimensional nonlinear non-homogeneous differential equations. Now through the function simplification, it becomes a 5-dimensional constant coefficient linear homogeneous differential equation system, and the analytical solution can be obtained for the two differential equations. In this paper, the Longge-Kuda method [12] is used for numerical solution.

3.2.4. Model test

Through the economic test of the model, $\hat{\beta}_1 = 0.0503$, is between 0 and 1, the sign of the regression coefficient, the size range and the economic theory and empirical expectations.

Goodness of fit, $R = 0.903, \overline{R} = 0.915$, 91.5% of the results of various factors can be explained by the change index established by the model.

Given the significance level, $\alpha = 0.05$, the model was tested by the model's overall significance F test and the parameter significance T test. The conclusion is consistent with the above test.

From the correlation graph and the residual graph, it can be seen that there is no correlation. Carry out further tests. There is no correlation between the partial correlation coefficient test model; the BG test considers that the auxiliary regression model is not significant, that is, there is no autocorrelation.

4. Power system equilibrium development dynamics model empirical

4.1.Forecast of installed capacity of various types of energy generation

The above model is used to calculate the installed capacity and proportion in 2020 and 2030, as shown in Figure 1-3.

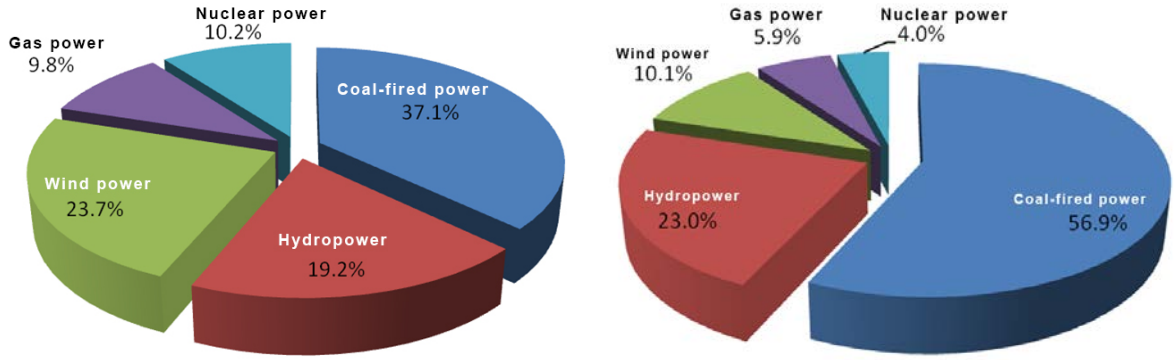


Figure 1. the forecast of all kinds of energy power installed capacity of total installed capacity in 2020 and 2030.

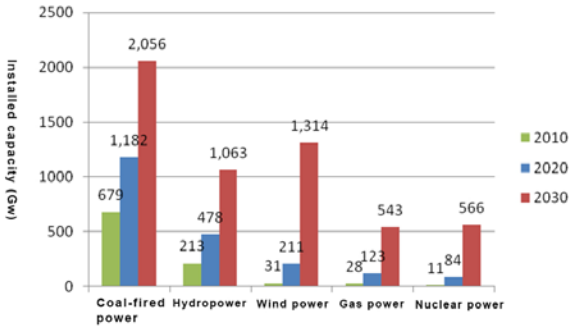


Fig2. All kinds of energy power capacity in 2020-2030 installations are compared with in 2010.



Fig3. All kinds of energy power capacity in 2010-2020 average annual compound growth rate and predict the future trend.

According to the calculation and analysis of the model: the growth rate of coal-fired power installation is relatively slow, the growth of hydropower installation is relatively stable, and the growth rate of wind power, gas and nuclear power is relatively fast, which is in line with the development policy of China's

power industry development: “Priority development of hydropower, optimization of development of coal-fired power, vigorously Develop nuclear power, actively promote new energy power generation, moderately develop natural gas centralized power generation, and develop distributed power generation according to local conditions.” From the perspective of power generation, it can be seen that by 2030, the proportion of various types of power generation installed capacity is relatively average, achieving The balanced development of various power supply structures avoids a single dependence on coal power.

4.2.Forecast of investment in various types of energy power generation

According to the model calculation and analysis, the total investment amount of the five types of fuel power generation will reach about 1.5 trillion to about 4.7 trillion yuan from 2020 to 2030. The proportion of investment in various types of energy power generation to total investment is shown in Figure 4-6.

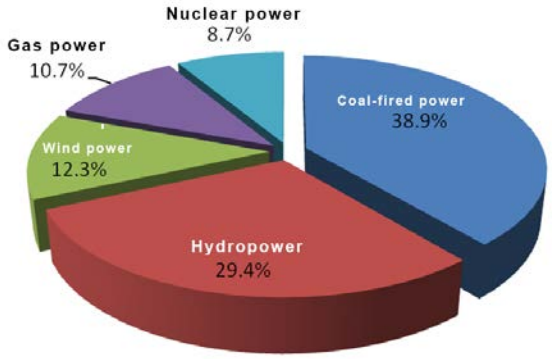


Fig 4. the predicted proportion of all kinds of power generation investment in 2020

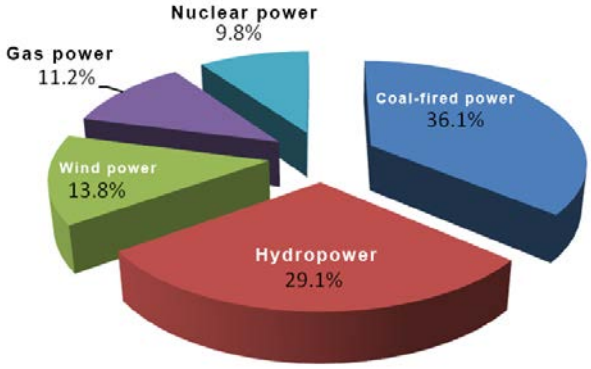


Fig 5. the predicted proportion of all kinds of power investment to total generation investment to total investment in 2030

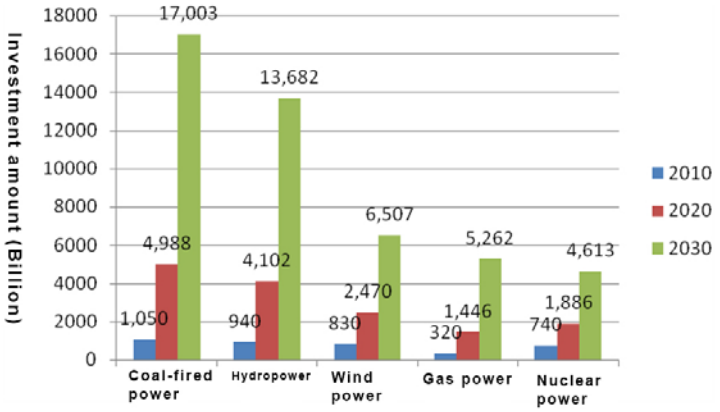


Fig6. In 2010 all kinds of models to predict energy investments are compared with 2020 and 2030

5. Conclusion

This paper uses the system engineering idea and the price growth theory to introduce the system competition and mutual control viewpoint into the power energy development system. Under the influence of factors such as interaction between factors and external policies, the power system equilibrium based on China's energy endowment is established. Develop a dynamics model. It can be seen from the model analysis that coal power will remain the main energy source in China for a long time, and the non-fossil energy scale development is a strategic direction [13]. It is estimated that the energy structure optimization period before 2020 will be mainly the clean and efficient development and utilization of coal-fired power. It will be the energy sector change period from 2020 to 2030, mainly the

clean energy, especially renewable energy alternative coal strategy, and the energy revolution after 2030. During the finalization period, a new energy system with “reasonable demand, green development, diversified supply, intelligent deployment, and efficient use” has been formed [14]. Therefore, in accordance with the "safe, economic, green, harmonious" planning principles and the concept of establishing a balanced energy development system, it is necessary to further optimize China's energy structure, improve system coordination, ensure energy supply security, and promote energy conservation and emission reduction [15]. Through the use of system engineering ideas and comprehensive decision-making system, an economical and reasonable power supply structure based on China's energy endowment is formed.

Through the analysis of the dynamic behavior analysis of the model, it has certain theoretical value and practical significance for further research on China's energy development. The empirical analysis proves that the model is highly feasible and can help the decision analysis.

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